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SPACE SYSTEMS ENVIRONMENTAL INTERACTION STUDIES

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Final testing, calibration and delivery of a new Digital Ion Drift Meter (DIDM) instrument occurred under Task 1 of this contract. Final details of the software effort which went into the work is reported. Some of the findings from the instrument characterization effort funded under phase 2 of of Task 1, are also shown. Phase 3 work is concerned with providing a DIDM-2 instrument for the CHAMP program. Instrument particulars and program details are provided.

On-going data analysis efforts contracted under Task 2, regarding the SPREE and OEDIPUS-C data sets is also reported. A detailed report on the software analysis tool developed for the work is presented. Under Task 3 (the Langmuir Turbulence [LaTUR} rocket investigation program) hardware design and software programming efforts are well underway. Details on the Data Processing Unit of the Energetic Particle Instrument (EPI) suite to be flown, are provided.

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Table of Contents

Section **Page**

1.0 Introduction 1

2.0 TASK #1 - DIDM Efforts 1
- 2.1 Program Definition 1
- 2.2 Summary of Activities 1
- 2.3 Instrument Software 1
- 2.4 Wedge & Strip 2
- 2.5 DIDM-2 Instrument 2
  - 2.5.1 Instrument Operation 5
  - 2.5.2 Command Definition 5
  - 2.5.3 Telemetry Definition 9
  - 2.5.4 Telemetry Format 10
- 2.5 Hardware 16
- 2.6 Planar Langmuir Probe (PLP) 17

3.0 TASK #2 – Data Analysis Efforts 19
- 3.1 Program Definition 19
- 3.2 Summary of Activities 19
- 3.3 OEDIPUS-C EPI Data Display Program 19

4.0 TASK #3 - OEDIPUS-C Efforts 31
- 4.1 Program Definition 31
- 4.2 Summary of Activities 31
- 4.3 DPU Functionality 32
- 4.4 LaTUR Telemetry Format 35

List of Figures

Number		Page
1	DIDM GSE Software Overview	2
2	Anode Detail showing actual structure & equivalent Pixel Array Map	3
3	DIDM Calibration Data showing Row, Column addressing & Count Maps	4
4	CHAMP Satellite Configuration & Payload Accommodation	4
5	DIDM-2 Signal Interface with CHAMP Spacecraft	16
6	Planar Langmuir Probe (PLP)	17
7	PLP Operation & Event Timing	18
8	Analysis Software Command Bar	20
9	Flight_Spectra/Electron Spectra (2 zones selected)	22
10	Flight_Spectra/Electron Spectra (all 8 zones selected)	23
11	2-D Zone Plot; Raw Counts Parameter Values	23
12	3-D Zone Plot; Raw Counts Parameter Values	24
13	Electron Spectral Display	25
14	Electron Frequency Resonances Display	26
15	Electron Energy Sweep & Spectra	26
16	Milli-Second Time Delay Plot	27
17	Energy Sweep Milli-Second Time Delay Plot	27
18	Raw Counts for Energy Sweep Milli-Second Time Delay Plot	28
19	Flight_Spectra/Tx Milli-Second Response	28
20	Major_Frame/Buncher	29
21	Energy Sweep MHz Plot	30
22	Raw Counts of Energy Sweep MHz Plot	30
23	Flight_Spectra/Passive Buncher Summation	31
24	LaTUR Payload Complement	32
25	DPU Dimensioned Schematic	33
26	Central Processor Board Schematic	34
27	High Frequency Board Schematic	35
28	Interface Board Schematic	35

List of Tables

Number		Page
1	DIDM Telemetry Command Header	6
2	High Voltage ON Command	6
3	High Voltage OFF Command	6
4	Configuration Select Command	6
5	Diagnostic Select Command	7
6	Map Bad Pixel for Sensor A	7
7	Map Bad Pixel for Sensor B	7
8	Configuration Define Command	8
9	Upload Adaptive Quadrature Boundaries	9
10	Output Data Header	10
11	Output Data Format	10
12	Science Data Format	10
13	Housekeeping Data Structure	11
14	Configuration Data Structure	11
15	Status Packet Data Structure	11
16	Science Header Data Structure	12
17	PLP Data Packet Structure #1	13
18	PLP Data Packet Structure #2	13
19	Drift Meter Data Packet Structure	14
20	RPA Data Packet Structure	14
21	Image Data Packet Structure	15
22	Command Echo Data Packet Structure	15
23	LaTUR Telemetry Structure	40

1.0 INTRODUCTION

This contract's objective is to further the understanding of near-earth environmental dynamics, by conducting both *In Situ* experimental studies, as well as, analytical and empirical studies of returned instrument data. The work is to be accomplished through three programs, subsequently identified as Task #'s 1, 2 and 3. A brief review of the scope of each program and a summary of the work performed during the report period follows. The material is presented in serial order, with Task #1 issues appearing first in Section 2.

2.0 TASK #1—DIDM EFFORTS

2.1 Program Definition

The objectives of this task are two-fold. They are: (1) develop the means to reliably measure ion densities in the range of 10^1 cm^{-3} to 10^7 cm^{-3}, by using digital rather than analog techniques, and thereby extend the existing dynamic range for such measurements by at least three orders of magnitude. (2) determine the incident angle of ions into the instrument within 3° in two dimensions, to allow accurate determination of ion drift velocities.

The work builds on that already undertaken by Amptek, Inc. under the Digital Ion Drift Meter (DIDM) program. There are three phases to the task. Phase 1 is essentially concerned with testing and calibrating the first instrument. The effort includes modifying existing mechanical and electronic designs as needed, as well as, designing and fabricating required test support equipment (hardware and software), to run the instrument during environmental and system integration tests. Phase 2 deals with the analysis of collected data during these exercises, in order to characterize instrument performance and improve both the overall mechanical design and instrument performance of subsequent instruments. A second unit is to be fabricated, tested and calibrated in Phase 3.

2.2 Summary of Activities

Phase 1 of this task was started and finished early in the report period. The instrument was delivered to PL/GPSG (now changed to AFRL/VSBS) for calibration and it was subsequently turned over to the space vehicle contractor (TRW Inc.) for integration onto the STEP 4 spacecraft. Details on instrument hardware and telemetry can be found in report PL-TR-96-2292. Section 2.3 provides final details on the software effort for the task. Much was accomplished under phase 2 as well, and this effort is largely concluded. One of its principal accomplishments is summarized in section 2.4. Phase 3 has recently been initiated and instrument component design and fabrication is underway. Details on the various elements of the DIDM-2 instrument are provided in Sections 2.5 and 2.6.

2.3 Instrument Software

The writing of instrument software to test the functionality of the various elements within the instrument, to support instrument calibration, and to verify proper instrument operation during the integration and test exercises on the spacecraft, was a major Phase 1 undertaking. Considerable time and effort was saved by consciously building on a few base software modules. There was for example, just one data display interface for all DIDM testing. Engineering diagnostic testing, environmental testing, instrument calibration, as well as, system integration and test exercises on the spacecraft, all made use of the same software modules for data display on the GSE terminal. This shortened the length of time needed for test support personnel to interface with the instrument, in order to become familiar with its operation. Essentially, it was only necessary to go through the process once, since the display parameters and operations remained unchanged. The system is WINDOWS® based and therefore is intuitively easy and straightforward to navigate within.

Necessarily, some customization was required to fulfill particular tasks. On such was the need to accommodate the requirements for instrument calibration. Specifically these were to provide the following in the saved data files: (i) science data in ASCII format; (ii) aperture orientation with respect to incident ion beam information and (iii) CALSYS (the calibration system controller) information regarding source and test chamber parameters. This was done by attaching a header and a footer of calibration specific information, ahead and after the body of science data. A CALSYS display tab appears in all versions of the software, but valid information is displayed only when the instrument is in fact being calibrated.

Another software task was to retrieve DIDM data from the 1553B data bus, which serves as the data interface with the instrument on the spacecraft, so that instrument performance monitoring during pre-delivery environmental tests, as well as, during system integration testing on the spacecraft might be achieved. To accomplish this, a separate piece of software was written to link into the 1553B bus, copy the DIDM messages and relay this information to a display module, which is the same module previously utilized for this purpose. Another feature of the code, is the ability to save to disk the retrieved data (saved in binary format to optimize storage space and portability). A top-level outline of the GSE software developed to support the instrument is shown in Figure 1.

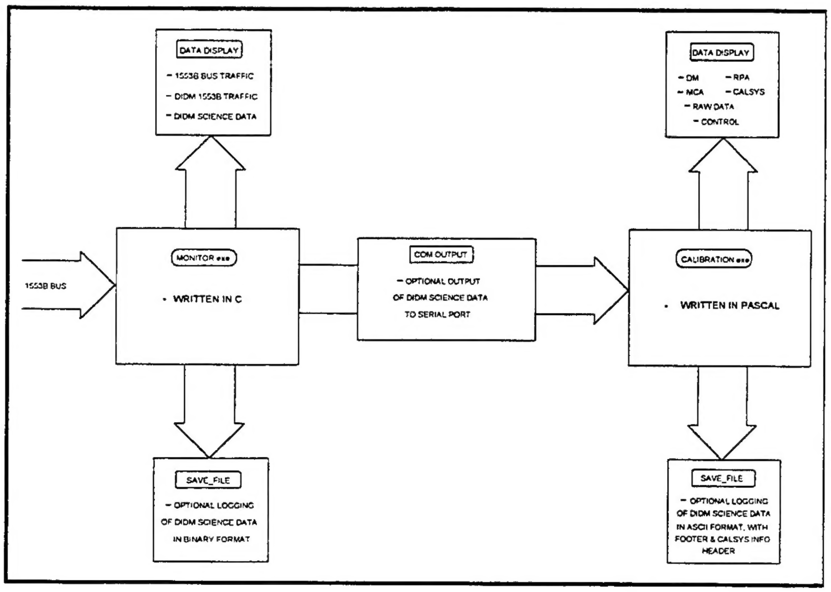


Figure 1: DIDM GSE Software Overview

2.4 Wedge & Strip Anode

Instrument test support occupied a significant portion of the time between delivery of the instrument to PL and delivery to TRW. In large measure, this was due to the uncertain knowledge of and variability in, the gain of the MicroChannel Plate (MCP) particle detectors. MCPs are central to the functionality of the instrument. Incident ions in a sensor are electrostatically steered to the active area of the MCP (there is one in each of the two sensors), by an attracting potential of -2100 volts. Each ion ultimately results in a cloud of electrons exiting the MCP, typically this cloud is around 10^6 electrons in size. The number of electrons so produced (generally referred to as the *MCP gain*), as well as, the energy distribution of ions in this cloud, are of key importance to the proper functionality of the detection electronics and consequently the instrument itself. Considerable time (almost a month and a half from beginning to end) was therefore spent in characterizing the instrument output for various sets of MCPs and in optimizing its output response. The actual process of instrument setup, data taking and subsequent instrument calibration was actually carried out by AFRL/VSBS personnel. They were tasked with assembling the sensors in particular, and with all matters which involved the use of the Ion Calibration Source facility (MUMBO) at AFRL.

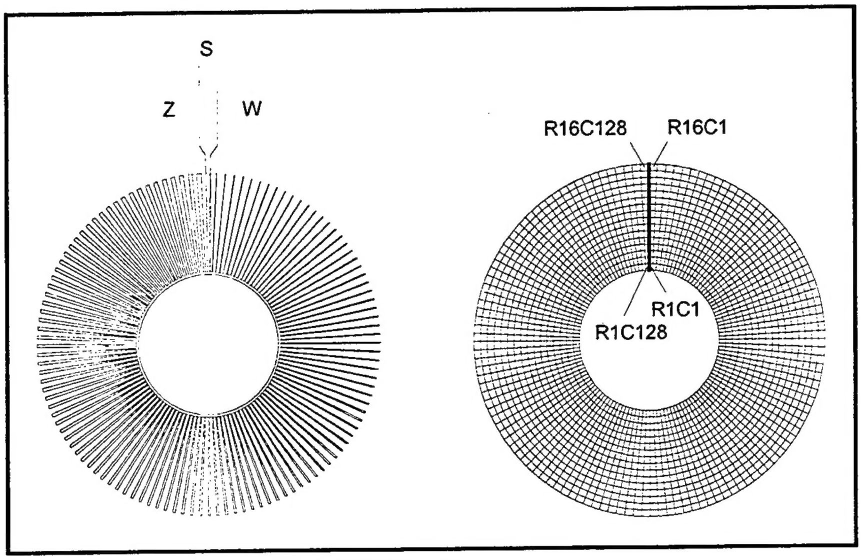
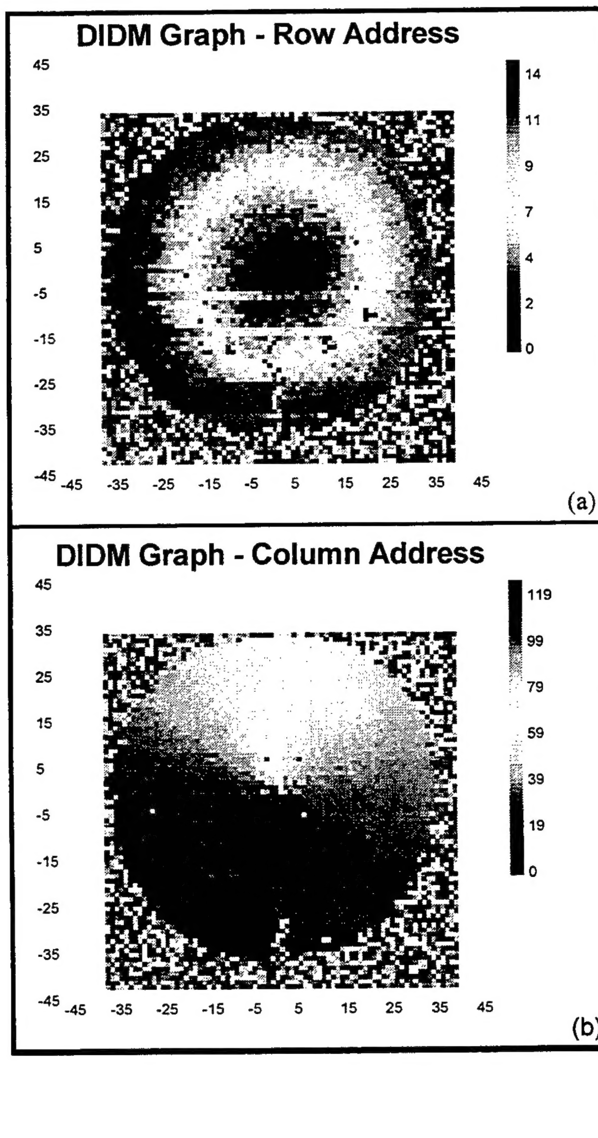


Figure 2:
Anode Detail showing actual structure & equiv. Pixel Array Map

Quite a bit was done to analyze the instrument's characterization and calibration data, in order to verify that the design was functioning as desired and to identify areas for optimization in subsequent efforts. These are essentially Phase 2 tasks and while much remains to be done to close out all concerns in this regard, it is unambiguously clear that the instrument design is a good one. This is true for both the electrostatic focusing aspects of the sensor assembly and the detection and processing ability of the electronics. This determination was made after a comprehensive set of data, obtained at the highest resolution afforded by the calibration facility, was carefully analyzed. Custom software was written to read-in and process the data in optimal fashion, and to then produce displays in a format from which the performance of the instrument can be clearly discerned.

The Wedge & Strip (W&S) Anode is the key detection element within DIDM. It is a two dimensional sensor, which indicates the location of incident particles (a cloud of electrons out of the MCP in this instance) in both angle from the axial axis through the center *(θ)*, as well as, azimuthally *(φ)* at any point on a circumference within its active surface. θ is mapped into 16 radial elements *(r)* and φ into 128 circumferential elements *(c)* on the anode surface. It is therefore possible to distinguish the location of an incident particle in any out of a total of 2048 (16 x 128) pixel elements. Figure 2 shows the actual anode structure and the pixel array mapping.



A stimulated (r, c) location relates directly to two components of the drift velocity of the incident ion, and a first measure of usefulness of the design is to show that indeed both radial and azimuthal discrimination can be accomplished by the system. Representative plots of the data appear in Figure 4; showing that indeed radial (Figure 3(a)) and circumferential (Figure 3(b)) mapping can be accomplished. Figure 3(c) shows the distribution of anode responses for events in one operational mode. The wedge shaped region is the location of the *zero crossing mask*, which serves to distinguish between the beginning and end of the array map.

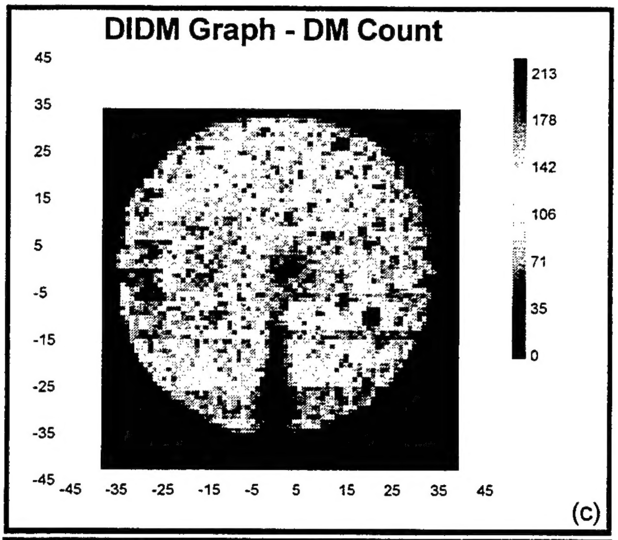


Figure 3: DIDM Calibration Data showing Row, Column addressing & Count Maps

2.5 DIDM-2 Instrument

Work commenced on the DIDM-2 towards the end of the first half of the report period. The instrument is to be flown on a German research spacecraft designated as the CHAllenging Minisatellite Payload (CHAMP). Perspective views of the satellite showing the DIDM mounting location, are shown in Figure 4. Amptek, Inc. personnel supported PL/GPSP at a DIDM Payload Detailed Design Review meeting at the CHAMP project office in Potsdam, Germany, which occurred in the middle of the report period. Several outstanding issues relating to schedule, mechanical and electrical interfaces, instrument operation and system testing procedures, were resolved then. It was also firmly reiterated that instrument power budget (5W), telemetry allocation (1500 baud) and delivery date (June 1st 1998) are fixed and cannot be exceeded. Given that the telemetry bandwidth is only one third the DIDM-1 allocation, and the data acquisition rate is close to fifty percent higher, there is considerable impetus to devise creative ways to process data differently, within the instrument.

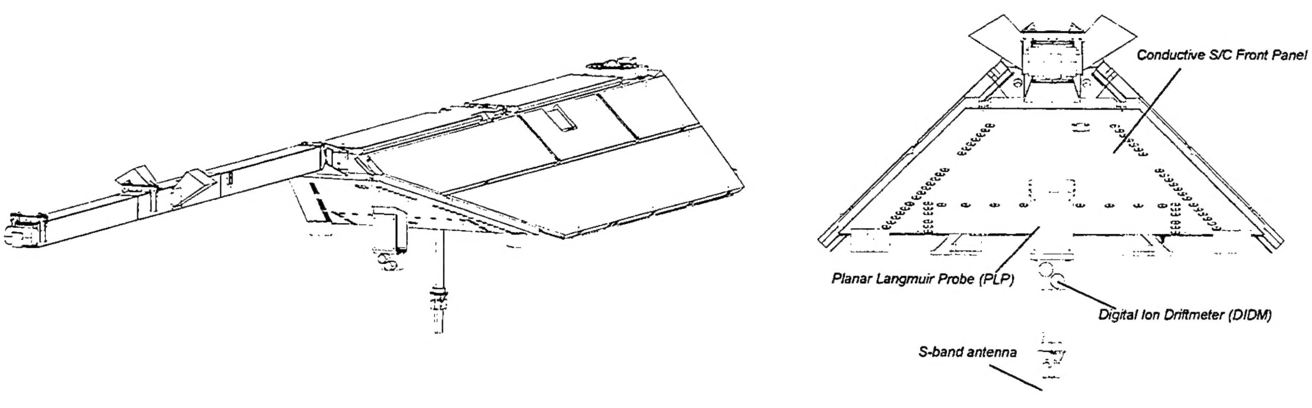


Figure 4: CHAMP Satellite & DIDM Payload Accommodation

Consequently, both the principals at AFRL and Amptek, Inc., have put quite a bit of time and effort into resolving just what the functional states of the instrument ought to be, and in defining its commanding and output telemetry structures. This interaction has resulted in the format for commands to, and output telemetry from the instrument, being fully defined. Some operational details and specifics of both command and telemetry formats follow.

2.5.1 Instrument Operation

DIDM-2 shall accommodate on-board processing of the individual drift images to produce either a final drift measurement, or a condensed summary of the data from which a drift measurement may be directly derived, and which will be fitted into the 10 byte Drift Meter Packet described as follows: 2 bytes contain the Row and Column of the peak pixel, 2 bytes contain the so-called *row and column moments,* which are derived from ratios of the quadrant sums from a synthetic adaptive aperture. The present design anticipates that this will be centered on the previous peak location. An additional 5 bytes will contain the four 10 bit sums over four column quadrants. The last bit will contain an estimate of the ion temperature. Any variation from this scheme shall fit within the allotted 10 bytes.

To understand the synthetic aperture, consider a contour of constant differential flux about the plasma drift vector. This circle in space will map to some space on the logical anode pixel array (16 x 128 pixels). The shape of this synthetic aperture as a function of zenith angle and flux contour will be determined from modeling efforts at AFRL and elsewhere. The area within the synthetic aperture is divided orthogonally into 4 quadrants. Ratios of the fluxes to pairs of the quads can be shown to give the plasma drift offset from the center of the synthetic aperture. When the plasma is incident along the aperture normal, the physical aperture is coincident with a flux contour, and a suitable quadrature can be had by simply dividing the pixel array into 4 column groups 4 x (16x32). These four sums are transmitted whole (4 numbers), and not as ratios (2 numbers), so that the total drift meter counts (an additional number), can also be obtained. The comparison of the fixed quad sums with the synthetic aperture ratios should provide second order drift information as well as a convenient measure of the light mass fraction.

DIDM will use both a configuration library and a mode stack that controls the operation of DIDM at all times. The library will have 8 read only configurations and 8 slots for configurations uploaded with the Configuration Define command. The mode stack has 16 slots that contain both a configuration and a duration. The Configuration Select command loads selected configurations from the library to the mode stack and sets the duration. DIDM moves from the top of the stack to the bottom in sequence, dwelling on each mode for the indicated duration. A duration of zero indicates a return to top of the stack. A maximum duration indicates indefinite dwell, or the default configuration. All stack modes below 0 or above the max duration are not accessed. The stack can be interrupted and reset to the top by the HV_OFF command. This stack structure will allow DIDM to be programmed to optimal modes for most or all of the interesting geophysical features encountered in an orbit. The stack reset can be used to synchronize the stack to the orbit ephemeral using either time-tagged commands or an onboard ephemeral program.

2.5.2 Command Definitions

DIDM has three configuration commands. These are:

- HV_ON: Switch ON -2100 V power supply.
- HV_OFF: Switch OFF -2100 V power supply.
- MOD_SEL: select one of 16 predefined operational modes and duration.

The following commands shall be applied for diagnostic purposes:

- DIA_SEL: select diagnostic tool, test pulser, return "bad" pixel map, return adaptive quadrature boundaries, set MCP gain.
- MAP_PXL_A: remove selected "bad" pixels from peak search for sensor A.
- MAP_PXL_B: remove selected "bad" pixels from peak search for sensor B.

The following commands shall be applied for scientific operation:

- MOD_DEF: define stored operational modes (Drift Meter, RPA, Image), RPA voltage sweep profile, summing, and MCP Full Width Half Max (FWHM).
- UPLOAD_QUAD: upload adaptive quadrature boundaries.

Header: All commands shall be preceded by a 4 byte header with the following parameters.

Table 1: DIDM Telemetry Command Header

CP_seqNo	CP_ChkVal	CP_Dlen						
Packet sequence number	Check value	Not used (b_{15}; MSB)	Not used (b_{14})	Not used (b_{13})	Not used (b_{12})	Not used (b_{11})	Not used (b_{10})	Data field length (b_9 .. b_0)
1 byte	1 byte	1 bit	1 bit	1 bit	1 bit	1 bit	1bit	10 bit

Each command and its respective parameters are listed in the following tables:

Table 2: High Voltage ON Command

Field No.	Name	Type	Size	Value	Range	Description
1	Command ID	HEX	8 bits	CONST	1	HV_ON (High Voltage On)

Table 3: High Voltage OFF Command

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	2	HV_OFF (High Voltage Off)/ Restart Configuration Stack

Table 4: Configuration Select Command

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	3	MOD_SEL (Mode Select)
2	Parameter 1	HEX	8 bits	VARIABLE	0-FF	Select Configuration
3	Parameter 2	HEX	8 bits	VARIABLE	0-FF	Configuration Duration

Select Configuration:

D7=0 Select from preset configurations
D7=1 Select from uploaded configurations
D6-4: Library of configurations A-H
D3-D0: Stack order for execution of selected configuration

Configuration Duration:

0= Go to top of stack
FF= Infinite (default mode)

Table 5: Diagnostics Select Command

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	4	DIA_SEL (Diagnostic Select)
2	Parameter 1	HEX	8 bits	VARIABLE	0-FF	Options
3	Parameter 2	HEX	8 bits	VARIABLE	0-FF	MCP Gains

Options:

- D7=1: Test pulse on
- D6=1: Send adaptive quadrature boundaries for both sensors
- D5=1 Send bad pixel map for both sensors

MCP Gains

- D7=1 Change sensor 1 MCP gain
- =0 Don't change
- D6-D4: Sensor 1 MCP Gains 1-8
- D3=1 Change sensor 2 MCP gain
- =0 Don't change
- D2-D0: Sensor 2 MCP Gains 1-8

Table 6: Map Bad Pixel for Sensor A

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	5	MAP_PXL_A (Map Bad Pixel for Sensor A)
2	Parameter 1	HEX	8 bits	VARIABLE	0-1	0 = Map Bad Pixel 1 = Reset Bad Pixel Map
3	Parameter 2	HEX	8 bits	VARIABLE	0	
4	Parameter 3	HEX	8 bits	VARIABLE	00-FF	Row for bad pixel #2 (FF if unused)
5	Parameter 4	HEX	8 bits	VARIABLE	00-FF	Column for bad pixel #2 (FF if unused)
6	Parameter 5	HEX	8 bits	VARIABLE	00-FF	Row for bad pixel #3 (FF if unused)
7	Parameter 6	HEX	8 bits	VARIABLE	00-FF	Column for bad pixel #3 (FF if unused)
8	Parameter 7	HEX	8 bits	VARIABLE	00-FF	Row for bad pixel #4 (FF if unused)
9	Parameter 8	HEX	8 bits	VARIABLE	00-FF	Column for bad pixel #4 (FF if unused)

Table 7: Map Bad Pixel for Sensor B

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	6	MAP_PXL_B (Map Bad Pixel for Sensor B)
2	Parameter 1	HEX	8 bits	VARIABLE	0-1	0 = Map Bad Pixel 1 = Reset Bad Pixel Map
3	Parameter 2	HEX	8 bits	VARIABLE	0	
4	Parameter 3	HEX	8 bits	VARIABLE	00-FF	Row for bad pixel #2 (FF if unused)
5	Parameter 4	HEX	8 bits	VARIABLE	00-FF	Column for bad pixel #2 (FF if unused)
6	Parameter 5	HEX	8 bits	VARIABLE	00-FF	Row for bad pixel #3 (FF if unused)
7	Parameter 6	HEX	8 bits	VARIABLE	00-FF	Column for bad pixel #3 (FF if unused)
8	Parameter 7	HEX	8 bits	VARIABLE	00-FF	Row for bad pixel #4 (FF if unused)
9	Parameter 8	HEX	8 bits	VARIABLE	00-FF	Column for bad pixel #4 (FF if unused)

Table 8: Configuration Define Command

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	7	MOD_DEF (Mode Define)
2	Parameter 1	HEX	8 bits	VARIABLE	0-FF	DM A mode
3	Parameter 2	HEX	8 bits	VARIABLE	0-FF	DM B mode
4	Parameter 3	HEX	8 bits	VARIABLE	0-FF	RPA A Configuration
5	Parameter 4	HEX	8 bits	VARIABLE	0-FF	RPA B Configuration
6	Parameter 5	HEX	8 bits	VARIABLE	0-FF	RPA A offset
7	Parameter 6	HEX	8 bits	VARIABLE	0-FF	RPA B offset
8	Parameter 7	HEX	8 bits	VARIABLE	0-FF	Options
9	Parameter 8	HEX	8 bits	VARIABLE	0-FF	PLP offset

DM A/B Mode:

D7-D5=000: no image packets
=001: 1 small stencil packet per DM sample
=010: 1 large stencil packet per 4 DM samples
=011: 1 background packet
=100: 2 background packets
=101: 4 background packets
=110: 8 background packets
=111: 8 background packets w/ sample&hold

D4-D3=00: Accum period=1/(DM samples/sec)
=01: Accum period=1/(DM samples/sec)/2
=10: Accum period=1/(DM samples/sec)/4
=11: Accum period= Spare

D2-D0=000: 0 DM samples/sec
=001: 1 DM sample/sec
=010: 2 DM samples/sec
=011: 4 DM samples/sec
=100: 8 DM samples/sec
=101: 16 DM samples/sec
=110: Spare
=111: Spare

RPA A/B Configuration:

D7-D6=00: 0 RPA packets in telemetry
=01: 1 RPA packet in telemetry (8 Hz)
=10: 2 RPA packets in telemetry (16 Hz)
=11: spare

D5 =0: RPA grounded
=1: RPA ON

D4=0: No time offset
=1: 4 step offset

D3-D0: RPA A/B sweep number (0=CAL)

RPA A/B Offset:

D7-D1: RPA offset (for non-CAL)
D0=0: Absolute Offset
D0=1: Offset Relative to S/C Potential (LP measurement)

Options:

D7-D5: Define as configuration A through H

D4-D3=00: LP OFF
=01: LP ON/Sweep 1
=10: LP ON/Sweep 2
=11: LP ON/Sweep 3

D2=1/0: Summing enabled/disabled

D1-D0=00: Select wedge table 0
=01: Select wedge table 1 (FWHM)
=10: Select wedge table 2
=11: Select wedge table 3

PLP Offset: 8 bit log compressed voltage offset

Table 9: Upload Adaptive Quadrature Boundaries

Field No.	Name	Type	Size	Value	Range	Description
1	Command_ID	HEX	8 bits	CONST	8	UPLOAD_QUAD (Upload adaptive quadrature boundaries)
2	Parameter 1	HEX	8 bits	VARIABLE	00-FF	Row 1
3	Parameter 2	HEX	8 bits	VARIABLE	00-FF	Column boundary corresponding to Row 1 (not used=FF)
4	Parameter 3	HEX	8 bits	VARIABLE	00-FF	Row 2
5	Parameter 4	HEX	8 bits	VARIABLE	00-FF	Column boundary corresponding to Row 2 (not used=FF)
6	Parameter 5	HEX	8 bits	VARIABLE	00-FF	Row 3
7	Parameter 6	HEX	8 bits	VARIABLE	00-FF	Column boundary corresponding to Row 3 (not used=FF)
8	Parameter 7	HEX	8 bits	VARIABLE	00-FF	Row 4
9	Parameter 8	HEX	8 bits	VARIABLE	00-FF	Column boundary corresponding to Row 4 (not used=FF)

There are no specific commands to handle instrument failure and contingency recovery. In the event of an operational anomaly, the only course of action would be to reinitialize the instrument by cycling power off and on as necessary.

2.5.3 Telemetry Definitions

The output telemetry data from DIDM-2 is comprised of measured data, as well as diagnostic housekeeping data. It is made up of a required Communication Packet header (packet sequence number checksum, data field length information and flags) followed by a Status packet (6 bytes), Planar Langmuir Probe (PLP) packet (8 bytes), a variable number of Drift Meter (DM) packets (10 bytes/packet), a variable number of Retarding Potential Analyzer (RPA) packets (18 bytes/packet), a variable number of Image packets (64 or 21bytes/packet), and a command echo transmitted in conjunction with the receipt of a command. Once per minute 4 house keeping parameters (1 byte each) and a Configuration packet (10 bytes) are included between the Communication Packet header and the telemetry.

The number of PLP, DM, RPA and Image packets is determined by the operational configuration of the instrument, and is contained in the 1 byte header belonging to the packets. The Command Echo packet occurs once per received command. The total size of the DIDM telemetry is variable, but can be selected by changing the operating configuration via ground command. It is expected that configurations will be chosen within the constraints of $\approx$1500 bits per second (bps), orbit average, and $\approx$5000 bps maximum burst rate. The higher data rates are expected to be used for observing interesting phenomena with increased resolution, and for diagnostics.

2.5.4 Telemetry Format

2.5.4.1 Header

All TM shall be preceded by the following 4 byte header.

Table 10: Telemetry Header

CP_seqNo	CP_ChkVal	CP_Dlen						
Packet sequence number	Check value	H/K Flag (b_{15}; MSB)	Not used (b_{14})	FDIR FLAG (b_{13})	Not used (b_{12})	Not used (b_{11})	Not used (b_{10})	Data field length (b_9 .. b_0)
1 byte	1 byte	1 bit	1 bit	1 bit	1 bit	1 bit	1bit	10 bit

- H/K flag: bit b_{15} shall indicate whether the CP_Data field contains any H/K data (b_{15}=1) or not (b_{15}=0).
- FDIR flag: bit b_{13} shall be set (b_{13}=1) when the OBDH is requested to turn off the DIDM.

2.5.4.2 Telemetry Structure

Once per minute DIDM will output the following Science and Housekeeping Data:

Table 11: Output Data Format

Header	Temperature Monitor	High Voltage Monitor	Low Voltage (+5V) monitor	Spare Monitor	DIDM Configuration	
4 bytes	1 byte	1 byte	1 byte	1 byte	10 bytes	

Status packet	0-1 PLP packet	0-32 DM packets	0-4 RPA packets	0-8 Image packets	Command Echo
6 bytes	1 byte header + 8 bytes/ packet	1 byte header + 10 bytes/packet	1 byte header + 18 bytes/packet	1 byte header + 64 or 21 bytes/packet	n bytes

Fifty-nine times per minute DIDM will output the following Science Data only:

Table 12: Science Data Format

Header	Status packet	0-1 PLP packet	0-32 DM packets	0-4 RPA packets	0-8 Image packets	Command Echo
4 bytes	6 bytes	1 byte header + 8 bytes/packet	1 byte header + 10 bytes/packet	1 byte header + 18 bytes/packet	1 byte header + 64 or 21 bytes/packet	n bytes

- The field command echo will only be sent in conjunction with the receipt of a command.

2.5.4.3 Housekeeping Data: (32 bits)

DIDM housekeeping will be sent once per minute. The H/K flag will be set to indicate the presence of housekeeping in the DIDM telemetry. The four bytes of housekeeping consists of:

Table 13: Housekeeping Data Structure

	Value	Size	Conversion	Comment
Byte0	TEMPMON	8 bits	Temp (deg C)=0.5767*Counts-50.853. 0 counts=-51C, 132 counts=25C, 255 counts=96C.	Temperature monitor
Byte1	HVMON	8 bits	-19.6V/count Nominal=-2100V=107 counts	High voltage monitor
Byte2	LVMON	8 bits	19.6mV/count Nominal=2.5V=127 counts	Low voltage (+5V) monitor
Byte3	spare	8 bits	spare	spare

2.5.4.4 DIDM Config Packet: (80 bits)

The DIDM Configuration Packet appears once per minute and indicates the configuration the instrument will be in for the following minute. This packet echoes the Configuration Definition that was last selected by the Configuration Select Command. It also contains diagnostic information.

Table 14: Configuration Data Structure

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Stencil/Image Packet			Accum Rate		DM Sample Rate			DM A mode
Byte1	Stencil/Image Packet			Accum Rate		DM Sample Rate			DM B mode
Byte2	RPA Packets		RPA Scale		RPA Sweep Number (0 = CAL)				RPA A Configuration
Byte3	RPA Packets		RPA Scale		RPA Sweep Number (0 = CAL)				RPA B Configuration
Byte4	RPA Offset (log compressed)							LP ref	RPA A Offset
Byte5	RPA Offset (log compressed)							LP ref	RPA B Offset
Byte6	Command ID		Pulser	PLP		SUM	Wedge Table		Options
Byte7	8 bit log compressed voltage								PLP Offset
Byte8	Previous command ID								Previous Command
Byte9	Adaptive Quad	Return Bad Pixel	Sensor 1 MCP Gain			Sensor 2 MCP Gain			Diagnostic Flags

2.5.4.5 Status Packet: (48 bits)

The status packet is located at the beginning of the DIDM science data. It contains a sync word, a status byte, the background pointer (which is used to determine the ring-column location of background image packets), and a time tag for synchronizing measurements to the 1 Hz clock.

Table 15: Science Data Format

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	0	1	0	1	1	0	1	0	Sync1=0x5A
Byte1	1	0	1	0	0	1	0	1	Sync2=0xA5
Byte2	HVON	Echo	spare					Reset	STATUS (Reset= 1 on reset/power up, = 0 after any command is received)
Byte3	8 bit background pointer								Background Pointer
Byte 4	Packet Sequence Number MSB								Frame Counter
Byte 5	8 bit time tag for synch pulse								Synch pulse time tag

2.5.4.6 Science Header: (8 bits)

The Science Header identifies the following packets as either DM, RPA, Image, or PLP packets. The Length field announces the number of packets (≤ 32) that will follow. There will be one header prior to a group of DM packets, a similar header prior to a group of RPA packets, a unique header prior to a group of image packets, and a unique header prior to a PLP packet. All four groups, with their associated headers, are optional. If the Report ID indicates Image, then the Length field is subdivided into 2 bits for Image ID and 3 bits for length (maximum of 8 image packets). Image packets can be defined as short, long, or background image packets (i.e. different Image IDs for different compression algorithms 21 / 64 log-compressed). If the Report ID indicates PLP, then there is no length field because all PLP packets are 8 bytes. The remaining bits in the PLP header field are used to identify specific PLP packet numbers.

Table 16: Science Header Data Structure

Science Header DM and RPA

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Report ID			Length (1-32 packets)					D7-D5=000: DM 1 =001: DM 2 =010: RPA 1 =011: RPA 2

Science Header Image

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Report ID			Image ID		Length (1-8 packets)			D7-D5=100 Image 1 =101 Image 2 D4-D3=00: Short =01: Long =10: Background

Science Header PLP

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Report ID			PLP Packet ID					D7-D5=110 PLP D4-D0= sequence number running from 0-14

2.5.4.7 Langmuir Probe Packet: (64 bits)

The Planar Langmuir Probe data is located at the beginning of the DIDM science data and will only be sent when the PLP is switched ON. The field length is always 8 bytes. PLP packets are sent once per second in a sequence of 15 packets that correspond to the 15 second PLP sweep. There are two types of PLP packets: Electrometer samples, and Floating Potential samples. The first 8 packets contain a total of 32 16 bit electrometer samples broken into least significant and most significant bytes. The next 7 packets in the sequence contain a total of 56 8-bit Floating Potential samples.

Table 17: PLP Data Packet Structure #1

	Descriptor	Comment
Byte0	ELEC 4*(Packet #)+1 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+1
Byte1	ELEC 4*(Packet #)+1 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+1
Byte2	ELEC 4*(Packet #)+2 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+2
Byte3	ELEC 4*(Packet #)+2 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+2
Byte4	ELEC 4*(Packet #)+3 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+3
Byte5	ELEC 4*(Packet #)+3 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+3
Byte6	ELEC 4*(Packet #)+4 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+4
Byte7	ELEC 4*(Packet #)+4 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+4

- Example: Packet # 0, Byte 0 contains the LSB for Electrometer sample 1 (i.e. 4*0+1 = 1), while Packet 7, Byte 7 contains the MSB for Electrometer sample 32 (i.e. 4*7+4 = 32)

Table 18: PLP Data Packet Structure #2

	Descriptor	Comment
Byte0	FP 8*(Packet#-8)+1	8 bit Floating Potential sample 8*(Packet#-8)+1
Byte1	FP 8*(Packet#-8)+2	8 bit Floating Potential sample 8*(Packet#-8)+2
Byte2	FP 8*(Packet#-8)+3	8 bit Floating Potential sample 8*(Packet#-8)+3
Byte3	FP 8*(Packet#-8)+4	8 bit Floating Potential sample 8*(Packet#-8)+4
Byte4	FP 8*(Packet#-8)+5	8 bit Floating Potential sample 8*(Packet#-8)+5
Byte5	FP 8*(Packet#-8)+6	8 bit Floating Potential sample 8*(Packet#-8)+6
Byte6	FP 8*(Packet#-8)+7	8 bit Floating Potential sample 8*(Packet#-8)+7
Byte7	FP 8*(Packet#-8)+8	8 bit Floating Potential sample 8*(Packet#-8)+8

- Example: Packet # 0, Byte 0 contains the Floating Potential sample 1 (i.e. 8*[8-8]+1 = 1) while Packet 14, Byte 7 contains the Floating Potential sample 56 (i.e. 8*[14-8]+8 = 56)

2.5.4.8 Drift Meter Packet: (80 bits)

The Drift Meter packet contains centroid and quadrature information for one image from one sensor. There is a one-to-one correspondence between the number of DM images per second (i.e. DM mode) and the number of DM packets in the telemetry. The packet contains the location of the image peak (12 bits), the two moments calculated from synthetic aperture adaptive quadrature (10 bits each), the four quadrants from column quadrature (10 bits each, log compressed), and the estimated ion temperature (8 bits).

Table 19: Drift Meter Data Packet Structure

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	x	PC6	PC5	PC4	PC3	PC2	PC1	PC0	Peak Column (0-127)
Byte1	MR9	MR8	MC9	MC8	PR3	PR2	PR1	PR0	Peak Row (0-15) + Moment MS bits
Byte2	MC7	MC6	MC5	MC4	MC3	MC2	MC1	MC0	Column moment LSB
Byte3	MR7	MR6	MR5	MR4	MR3	MR2	MR1	MR0	Row moment LSB
Byte4	QCA7	QCA6	QCA5	QCA4	QCA3	QCA2	QCA1	QCA0	Quadrant A LSB
Byte5	QCB7	QCB6	QCB5	QCB4	QCB3	QCB2	QCB1	QCB0	Quadrant B LSB
Byte6	QCC7	QCC6	QCC5	QCC4	QCC3	QCC2	QCC1	QCC0	Quadrant C LSB
Byte7	QCD7	QCD6	QCD5	QCD4	QCD3	QCD2	QCD1	QCD0	Quadrant D LSB
Byte8	QCD9	QCD8	QCC9	QCC8	QCB9	QCB8	QCA9	QCA8	Quadrant A-D MS bits
Byte9	IT7	IT6	IT5	IT4	IT3	IT2	IT1	IT0	Ion Temperature

2.5.4.9 RPA Packet: (144 bits)

The RPA packet contains eight RPA samples. Depending on RPA mode, there will be 0 RPA packets (no RPA), 1 RPA packet (RPA=8 Hz) or 2 RPA packets (RPA=16 Hz) in the telemetry per active RPA (i.e. both sensors @ 16 Hz=4 packets.) The RPA packet contains 8 RPA count samples (10 bits each) and 8 corresponding gate count samples (8-bits each, log-compressed.).

Table 20: RPA Data Packet Structure

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	R1-7	R1-6	R1-5	R1-4	R1-3	R1-2	R1-1	R1-0	RPA sample 1 LSB
Byte1	R2-7	R2-6	R2-5	R2-4	R2-3	R2-2	R2-1	R2-0	RPA sample 2 LSB
Byte2	R3-7	R3-6	R3-5	R3-4	R3-3	R3-2	R3-1	R3-0	RPA sample 3 LSB
Byte3	R4-7	R4-6	R4-5	R4-4	R4-3	R4-2	R4-1	R4-0	RPA sample 4 LSB
Byte4	R4-9	R4-8	R3-9	R3-8	R2-9	R2-8	R1-9	R1-8	RPA 1-4 MS bits
Byte5	R5-7	R5-6	R5-5	R5-4	R5-3	R5-2	R5-1	R5-0	RPA sample 5 LSB
Byte6	R6-7	R6-6	R6-5	R6-4	R6-3	R6-2	R6-1	R6-0	RPA sample 6 LSB
Byte7	R7-7	R7-6	R7-5	R7-4	R7-3	R7-2	R7-1	R7-0	RPA sample 7 LSB
Byte8	R8-7	R8-6	R8-5	R8-4	R8-3	R8-2	R8-1	R8-0	RPA sample 8 LSB
Byte9	R8-9	R8-8	R7-9	R7-8	R6-9	R6-8	R5-9	R5-8	RPA 5-8 MS bits
Byte10	G1-7	G1-6	G1-5	G1-4	G1-3	G1-2	G1-1	G1-0	Gate sample 1 LSB
Byte11	G2-7	G2-6	G2-5	G2-4	G2-3	G2-2	G2-1	G2-0	Gate sample 2 LSB
Byte12	G3-7	G3-6	G3-5	G3-4	G3-3	G3-2	G3-1	G3-0	Gate sample 3 LSB
Byte13	G4-7	G4-6	G4-5	G4-4	G4-3	G4-2	G4-1	G4-0	Gate sample 4 LSB
Byte14	G5-7	G5-7	G5-7	G5-7	G5-7	G5-7	G5-7	G5-7	Gate sample 5 LSB
Byte15	G6-7	G6-6	G6-5	G6-4	G6-3	G6-2	G6-1	G6-0	Gate sample 6 LSB
Byte16	G7-7	G7-6	G7-5	G7-4	G7-3	G7-2	G7-1	G7-0	Gate sample 7 LSB
Byte17	G8-7	G8-6	G8-5	G8-4	G8-3	G8-2	G8-1	G8-0	Gate sample 8 LSB

2.5.4.10 Image Packet: (168 or 512 bits, depending on DM mode)

The Image packet contains a subset of the pixel map from either DM A or DM B. The packet is constructed in one of three distinct formats. The smallest is 21 log-compressed pixels (for the 'small stencil') in a 3 ring by 7 column format. When 'small stencil' is selected, one 3x7 stencil is taken from each DM sample, with the stencil centered on the peak pixel. (The peak location can be obtained from the corresponding DM packet.). For the 'large stencil', 62 log-compressed pixels are taken from every fourth DM sample (but not less than one/second), and are combined with the peak ring-column address to form a 64-byte packet. The 'background' packet is also 64-bytes in length, but contains 64 log-compressed pixels.

Table 21: Image Data Packet Structure

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0									Image data
Byte1									Image data
:									Image data
Byte64									Image data

2.5.4.11 Command Echo Packet: (24,32, 40, or 88 bits)

The Command Echo packet appears in the telemetry immediately following the receipt of a command, and for one second only. The report ID identifies this packet as a command echo packet and identifies the number of parameters associated with the echoed command (0, 1, 2, or 8). This byte determines the total length of the command echo packet. The CP_SeqNo is the communication packet number, with which the telecommand has been sent. The Command ID is the command that has been sent.

Table 22: Command Echo Data Packet Structure

Field No.	Name	Type	Size
Byte0	Report ID	HEX	8 bits
Byte1	CP_SeqNo	HEX	8 bits
Byte2	Command_ID	HEX	8 bits
Byte 3	Parameter	HEX	8 bits
↓	↓	↓	↓
Byte 10	Parameter	HEX	8 bits

2.6 Hardware

In addition to settling software concerns, significant success was also realized in resolving hardware related issues as well. One such is the signal interface between DIDM-2 and the CHAMP spacecraft. DIDM-1 was built to accommodate a MIL-STD-1553 signal interface and the RS-422 interface on CHAMP therefore necessitated a change to the signal interface of the instrument. Due to fiscal concerns, a full redesign of the instrument to incorporate this capability, as well as, other grounding and signal isolation requirements, was not possible and it was therefore necessary to adopt some creative undertakings to satisfy these requirements, within the constraints imposed by the DIDM-1 design.

As an example, signal isolation is satisfied on a MIL-STD-1553 signal interface by means of the transformer coupled hardware. For RS-422 interfaces, optocoupled devices, powered by an isolated power supply are commonly used. In the absence of such a supply, DIDM-2 makes use of the spacecraft's power supply unit, by tapping one of isolated interface handshaking lines (CTS), to power its transmit driver. An acceptable form of instrument isolation and interfacing with the spacecraft was thereby devised. A schematic of the interface hardware is shown in Figure 5.

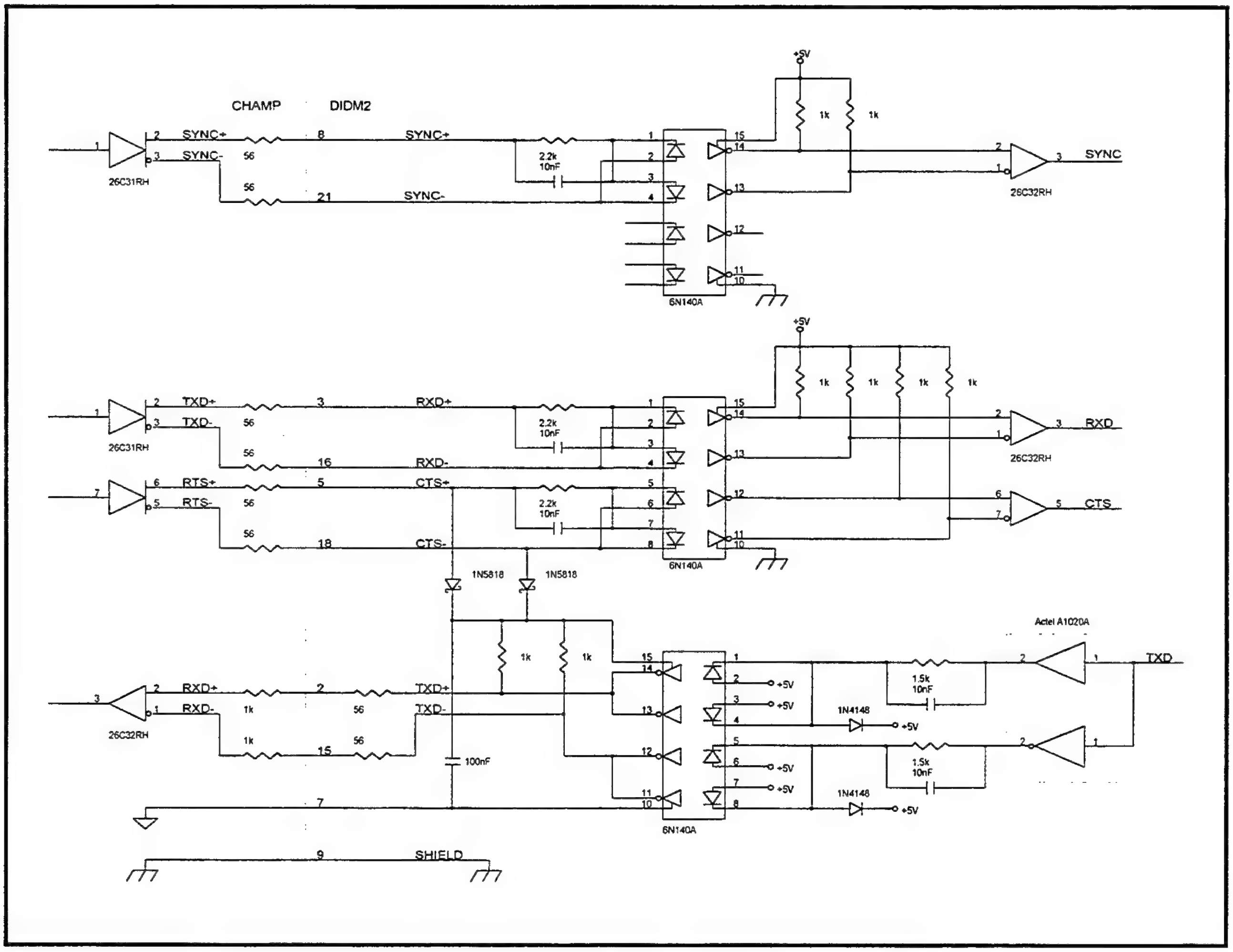


Figure 5: DIDM-2 Signal Interface with CHAMP spacecraft

2.7 Planar Langmuir Probe (PLP)

This was a relatively late addition to the DIDM-2 hardware complement. It was added after recognition was made that given the CHAMP spacecraft's design and DIDM's mounting location, knowledge of the vehicle's floating potential would be particularly useful in analyzing instrument data. There was particular concern that the instrument would be shadowed by a protruding magnetometer boom, and that the trajectory of ambient particles to the sensors would be affected. A Langmuir Probe in close proximity to the instrument can accurately provide a good measure its floating potential and the density of the ambient particles as well. Corroborating evidence of the verisimilitude if the DIDM measurements can thus be obtained. A two-dimensional planar Langmuir Probe was chosen instead of a perhaps more desirable spherical probe, due to accommodation limitations on the spacecraft.

The stipulated requirements for the device were as follows: (i) measure ion and electron current in the range 5 nA to 5 mA. (ii) sweep collecting plate voltage from –1V to +1 V with respect to a commandable offset. Offset voltage to range from –1 V to +5 V. Sweep duration to be 1 second. (iii) PLP to have alternate capability of floating to the spacecraft potential, when sweeping voltage and collecting current is not on-going. (iv) sample rate to be once per second over 15 second period with the ratio of floating to sweeping time to be 14:1. A drawing of the device is shown in Figure 6. A schematic of its electronics design and event timing is shown in Figure 7.

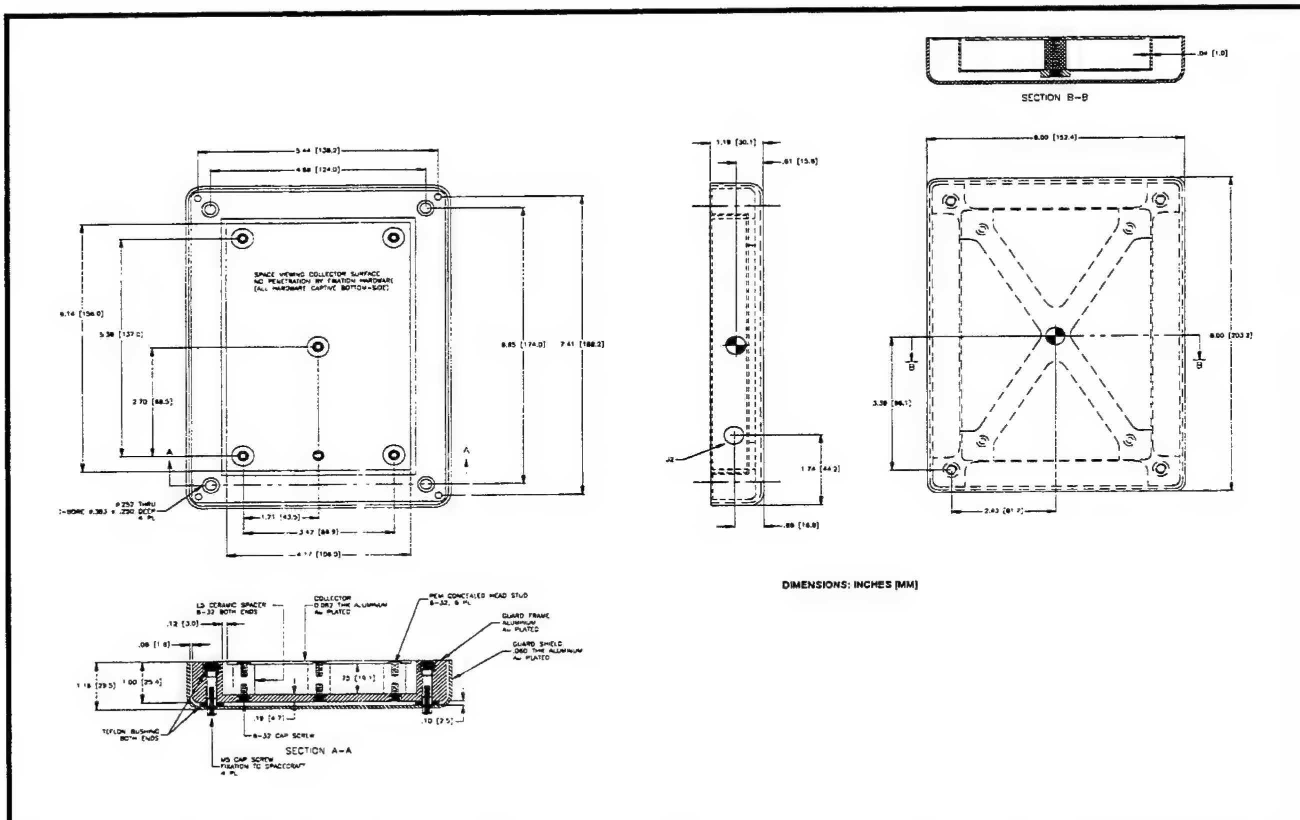


Figure 6. Planar Langmuir Probe (PLP)

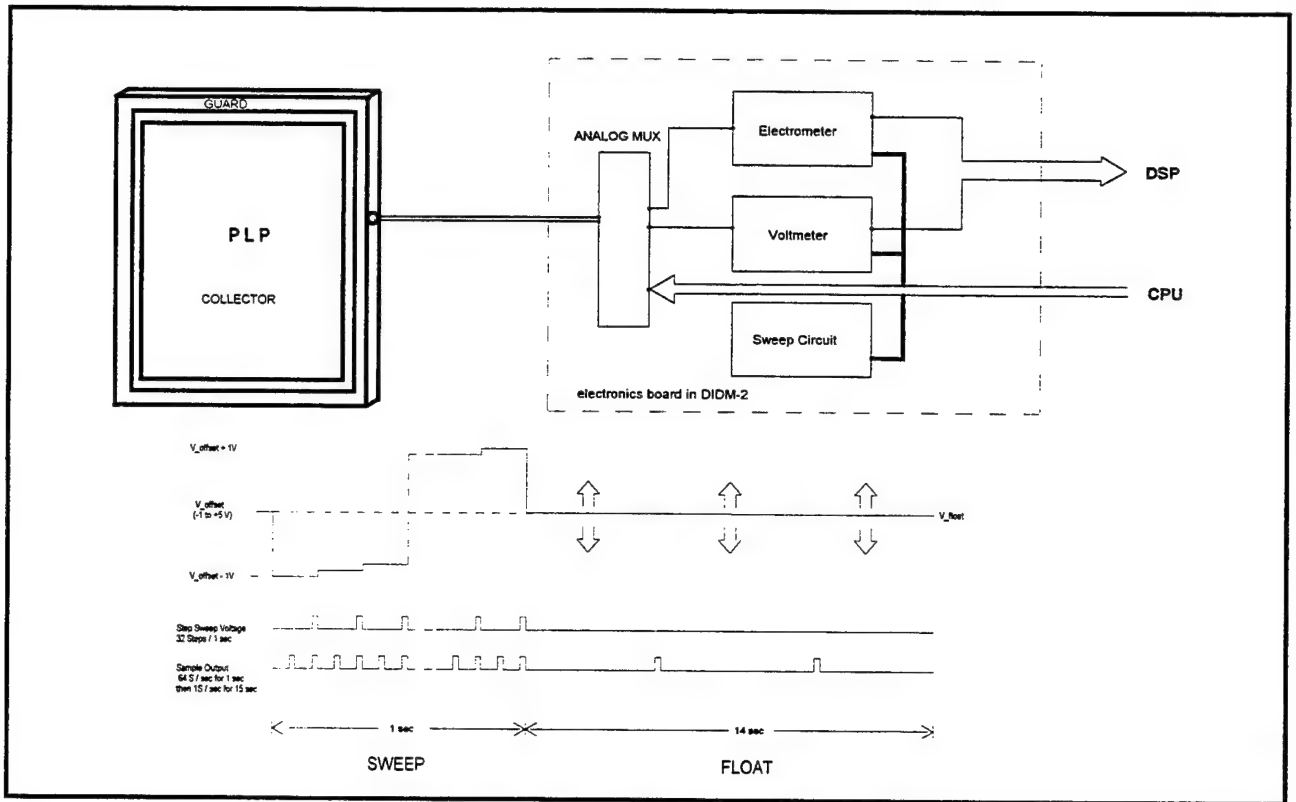


Figure 7. PLP Operation & Event Timing

The final design capability of the instrument can be summarized as follows:

- Sweep Mode: Bias voltage sweep to the PLP (collector and guard) from –1V to +1V.
  — with respect to an offset voltage in the range of –1V to +5V or to a previously measured floating potential (V_f).
- 1 sec sweep duration in thirty-two 31.25 mV steps.
- Electrometer circuitry measures current from ± 5 nA to ± 5 mA.

— Full scale output for stage 1 corresponds to			5.0 mA
stage 2	"	"	165.25 μA
stage 3	"	"	4.88 μA
stage 4	"	"	152.59 nA

- Sweep mode output sampled 64 times per second by a 12 bit ADC and telemetered 32 times per second.
- Oversampling allows gain switching before telemetry sample is taken.
- The approximate resolution per bit of the electrometer is as follows:

  stage 1 is 2.44 μA
  stage 2 is 76.29 nA
  stage 3 is 2.38 nA
  stage 4 is 74.5 pA

- Float Mode: after the sweep, the PLP is unbiased and allowed to float for an interval of 14 seconds. The guard follows the plate potential.
  — electronics switched to voltage measurement circuitry.
- V_f measured once per second over a range of ± 10 V with a resolution of 4.88 mV per bit.

3.0 TASK #2—DATA ANALYSIS EFFORTS

3.1 Program Definition

The objective of this task is to analyze the interactions between spacecraft and the space environment in order to advance the understanding of dynamic space plasma effects. Efforts will be directed toward the analysis of data from the Tethered Satellite Systems flights (TSS-1 and TSS-1R), and the Space Wave Interactions with Space Plasmas Experiment (SWIPE) flown on the Observation of Electric-field Distributions in Ionospheric Plasma: a Unique Solution (OEDIPUS-C) mission.

The work will be concerned with characterizing electron beam-space plasma interactions and the dynamic I-V particulars of a magnetized plasma. Such knowledge of the space plasma environment and of its interactions with spacecraft, is critical to the design of future platforms in space. The proposed work will advance the state-of-the-art capability of Air Force assets in that environment.

3.2 Summary of Activities

Work continued on the analysis of both the TSS and OEDIPUS-C mission data throughout the report period. TSS-1R correlator data in particular was closely looked at, in both the high and low frequency regimes, I order to completely prepare two papers for inclusion in a special TSS-1R edition of Geophysical Research Letters. The camera-ready version of two papers which were accepted for publication in the Journal of Geophysical Research were also submitted during this period. In addition, papers were prepared for and presented at scientific meetings in the U.K., France and Canada during the report period, on both the TSS and OEDIPUS-C data sets. By all accounts, the results were favorably received.

Work has also commenced on software development for the analysis of Langmuir Turbulence (LaTUR) rocket launch data. The basic interface has been completed and work is in hand on the decommutation module that retrieves the different science streams. An initial plan has been devised for the design of the different graphics modules (corresponding to these different science dataset types). The software was written in the existing Microsoft VisualBasic3. Delivery is expected soon however, of the MS Visual Studio (including Visual Basic 5) and the software will be updated to run on this latest VB version. It is expected that running the software, compiled, in VB5 will provide a significant program running speed increase (up to 20 times over VB3).

An in-depth description of the functionality of the existing analysis software follows. It is illustrative of the current state of the OEDIPUS-C algorithms that are employed to process Energetic Particle Instrument (EPI) sensor data in the correlator portion of the DPU.

3.3 OEDIPUS-C EPI Data Display Program

The program was written to analyze the EPI data on PC machines using Microsoft Windows 3.0 or Windows 95. As the EPI data is complex being a function of time, energy step, frequency step, transmitter mode etc a wide range of displays have been developed for analysis of the data.

3.3.1 Command Bar

On start up and present whenever data is being analyzed is the main command bar. It is shown below in Figure 8:

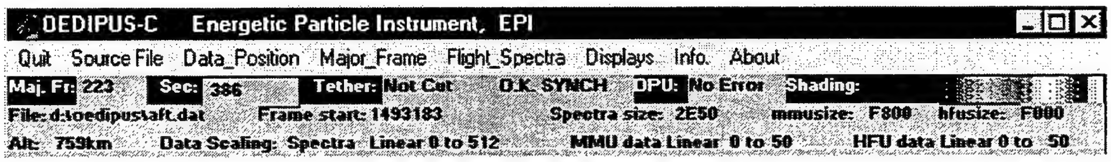


Figure 8: Command Bar

From the pull down menu items various options are available:

Option	Sub-Option	Action
Quit		Exit program
Source File	Change file	Select file to use as data source
	View Source	Raw HEX data dump for debug use
	Synch Searches	Check on Synchs in data for debug use
Data_Position		Select position in data for displays to start:
	By flight time	time in seconds from launch (Crude time position!)
	By major frame number	number of major frames from launch
Major_Frame		Display one Major frame against time in frame:
	Electron Spectra	spectra from all eight zones
	mS time delay plots	four zone pairs time delay for selected energy pair
	MHz ACF plots	four zone pairs ACF lag for selected energy pair
Flight_Spectra		Plots of large sections or whole flight versus time:
	Electron Spectra	All 8 or selected pair of zones: count/energy/time
	Electron Frequency Res.	Selected range of zones: count /TX frequency/time
	TX ms response	Counts TX ON - counts TXOFF frequency/time
	Passive Buncher sum.	Sum HF ACF over many frames
Displays	Scaling	Interactive set scaling of plots
	Window Persistence	Hard/Soft
	Shading	Color/Gray
	Print Displays	Select display to print on local print device
Info	TX Cycles	Copy of pre-cut/post-cut operation modes
	Program Development	Latest changes, things to do,& date of revision
About		Author & contact info.

Each of the displays called up from the command bar can co-exist with the command bar on a Windows screen set up as 640 x 480 pixels 256 colours. However, as best data interpretation comes from multi-display assimilation a larger screen size is preferable, e.g. 1280 x 1024 pixels, 256 colors. Note that several of the windows call up by cursor position another detailed plot. To avoid the original screen being erased, the option Display/Window Persistence/Hard should be set on the command bar at the start of program use. However, this slows down screen writing considerably! Note the color displays can be set to grayscale from Display/Shading options.

The command bar includes simple monitoring of each major frame as it is read from the file:

Maj. Fr:	Number of present major frame
Sec:	seconds of start of this major frame from launch
Tether:	'Not Cut' or 'Cut' from flag onboard
LOST SYNCH / OK SYNCH	Monitors program synching to data format
DPU:	'No Error' or 'Error' from flag generated by EPI CPU
Shading	Sample Color or Grey scale Bar in use
File	Filename currently in use for data source
Frame Start byte:	Position of 1st byte of Frame in data file (Debug / monitor use)
Spectra size:	Size of Spectral Data from frame header (Debug / monitor use)
mmusize:	Size of MMU Data-set from frame header (Debug /monitor use)
hfusize:	Size of HFU Data-set from frame header (Debug /monitor use)
Alt:	Altitude in km
Scaling Spectra	Spectral data: linear or log scaling and range
Scaling mmu	mmu data: linear or log scaling and range
Scaling hfu	hfu data : linear or log scaling and range

The program files consist of the following:

OEDIPUS.EXE (204 kbytes); ACFANN.DLL(7 kbytes); VBRUN300.DLL(356 kbytes).

3.3.2 Displays Available:

A. Electron Energy Step Count Sums
B. Millisecond Time response data
C. MHz Buncher autocorrelator data

Electron Spectra data is available for all eight zones while Millisecond and MHz data are available for four zone pairs.

NOTE: Displays illustrated below use the Display/scaling settings:

Spectral data:	Log scaling 0-1000	(Select Displays/Scaling; Enter: Y; G; 1000)
MMU and HFU data :	Linear 0-43	(Enter returns for these default values)

3.3.3 Electron Energy Step Count Sums

In the following display selections electron counts are summed over an energy step and plotted versus energy/time or frequency/time.

In both the selected pair of zones and all eight zone displays the time scale can be varied by selecting the plot time scale option. This prompts the user for the number of major frames to plot accross the screen. Note that clicking the cursor on the screen at a given point brings up another window on which 2-D plots of a single energy sweep spectra are shown for all eight zones:

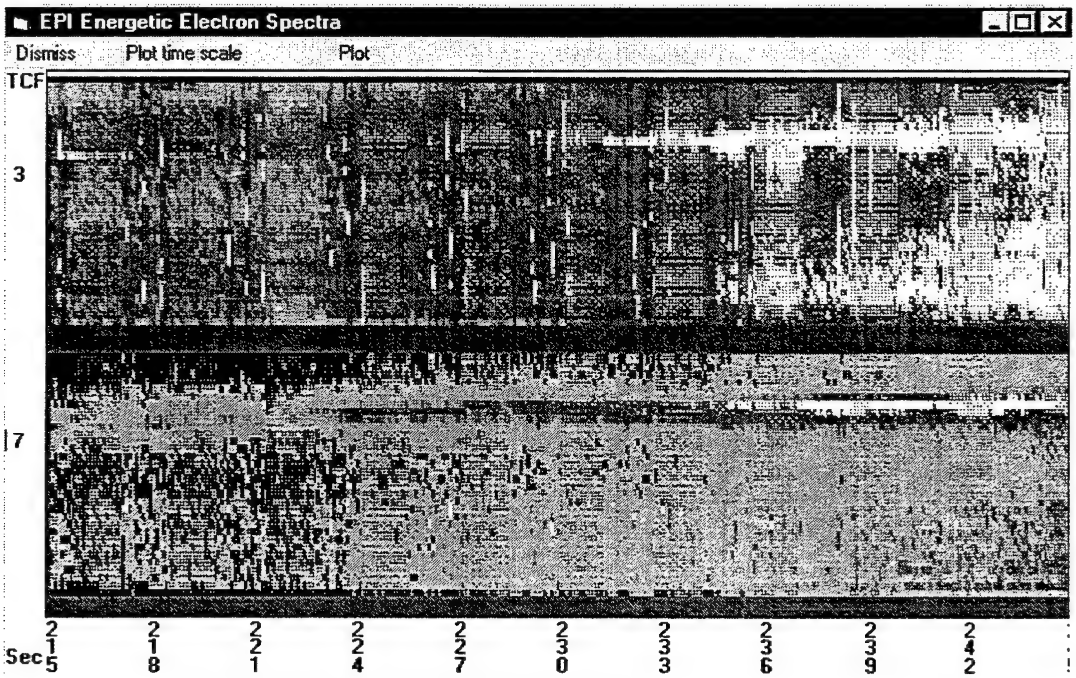


Figure 9: Flight-Spectra / Electron Spectra (2 zones selected)

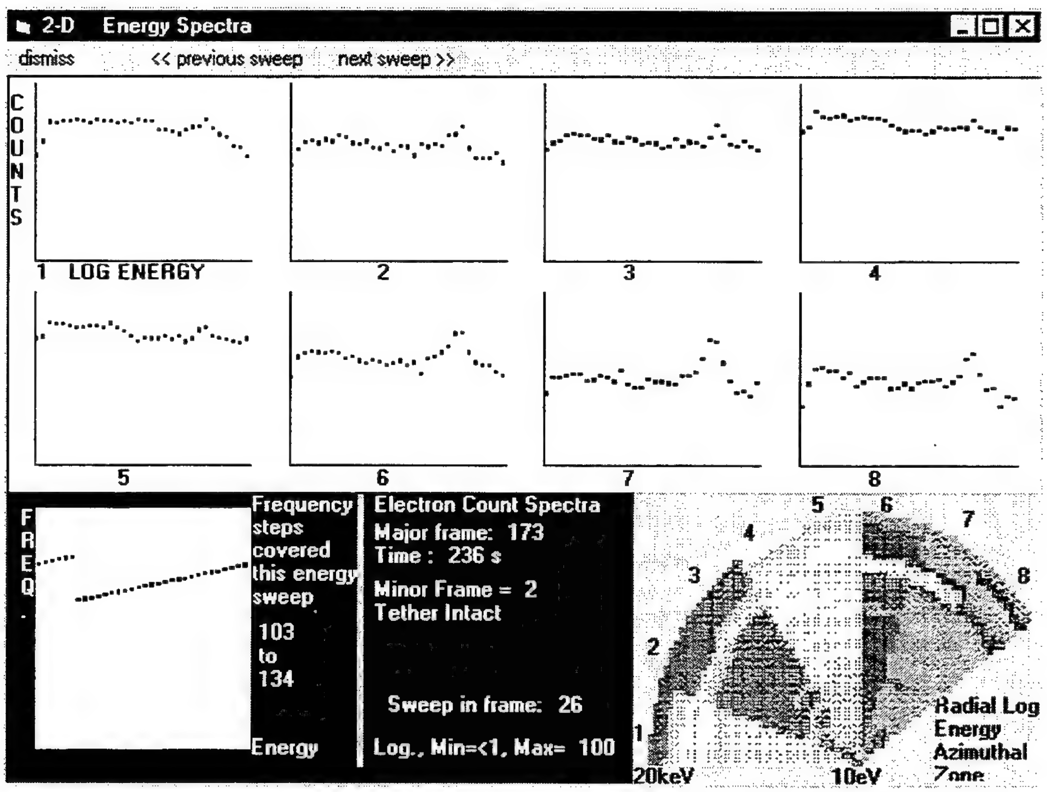


Figure 10: Flight-Spectra / Electron Spectra (all 8 zones selected)

Clicking the mouse on any one of the 2-D zone plots above gives a list of raw count values versus energy, frequency, time order and TX voltage:

Raw Count Data Values:

Unit # 2 (1 of 8)

Estep.	count.	Fstep.	Minor fr.	TX setup.		Time order.	HiRes Ebin
0	537	129	2	100v	6275 kHz	26	8
1	621	130	2	100v	6325 kHz	27	9
2	662	131	2	100v	6375 kHz	28	9
3	673	132	2	100v	6425 kHz	29	10
4	659	133	2	100v	6475 kHz	30	10
5	679	134	2	100v	6525 kHz	31	11
6	668	103	2	100v	4975 kHz	0	11
7	698	104	2	100v	5025 kHz	1	12
8	689	105	2	100v	5075 kHz	2	12
9	659	106	2	100v	5125 kHz	3	13
10	649	107	2	100v	5175 kHz	4	13
11	668	108	2	100v	5225 kHz	5	14
12	636	109	2	100v	5275 kHz	6	14
13	628	110	2	100v	5325 kHz	7	15
14	653	111	2	100v	5375 kHz	8	15
15	617	112	2	100v	5425 kHz	9	0
16	643	113	2	100v	5475 kHz	10	0
17	639	114	2	100v	5525 kHz	11	1
18	590	115	2	100v	5575 kHz	12	1
19	649	116	2	100v	5625 kHz	13	2
20	639	117	2	100v	5675 kHz	14	2
21	653	118	2	100v	5725 kHz	15	3
22	646	119	2	100v	5775 kHz	16	3
23	698	120	2	100v	5825 kHz	17	4
24	707	121	2	100v	5875 kHz	18	4
25	755	122	2	100v	5925 kHz	19	5
26	628	123	2	100v	5975 kHz	20	5
27	574	124	2	100v	6025 kHz	21	6
28	574	125	2	100v	6075 kHz	22	6
29	574	126	2	100v	6125 kHz	23	7
30	604	127	2	100v	6175 kHz	24	7
31	551	128	2	100v	6225 kHz	25	8

Figure 11: 2-D Zone Plot; Raw Counts Parameter Values

Alternatively clicking the mouse on the 3-D zone pie chart gives all zone raw counts versus TX frequency and voltage:

Raw Count Data Values:

All 8 units:

Estp.	Cnt1.	Cnt2.	Cnt3.	Cnt4.	Cnt5.	Cnt6.	Cnt7.	Cnt8.	TX setup	
0	590	537	625	728	731	514	418	347	100v	6275 kHz
1	668	621	659	752	742	625	514	477	100v	6325 kHz
2	776	662	673	839	824	649	514	557	100v	6375 kHz
3	770	673	698	807	812	659	522	569	100v	6425 kHz
4	784	659	712	803	816	653	530	551	100v	6475 kHz
5	784	679	703	812	807	646	530	551	100v	6525 kHz
6	789	668	698	816	798	656	492	514	100v	4975 kHz
7	784	698	684	793	793	646	497	537	100v	5025 kHz
8	767	689	679	803	803	621	522	460	100v	5075 kHz
9	789	659	703	812	807	628	514	487	100v	5125 kHz
10	778	649	668	798	793	604	487	514	100v	5175 kHz
11	781	668	662	803	820	590	551	514	100v	5225 kHz
12	767	636	689	793	793	612	471	514	100v	5275 kHz
13	781	628	679	761	773	599	453	447	100v	5325 kHz
14	773	653	649	739	746	580	453	453	100v	5375 kHz
15	789	617	662	728	720	590	501	477	100v	5425 kHz
16	778	643	659	731	735	604	487	447	100v	5475 kHz
17	778	639	636	735	731	580	487	482	100v	5525 kHz
18	731	590	646	716	731	595	477	492	100v	5575 kHz
19	731	649	684	728	749	530	471	492	100v	5625 kHz
20	720	639	643	755	724	617	522	501	100v	5675 kHz
21	707	653	668	742	746	632	522	466	100v	5725 kHz
22	731	646	662	742	712	653	544	487	100v	5775 kHz
23	746	698	646	755	731	684	621	522	100v	5825 kHz
24	752	707	694	746	781	761	724	617	100v	5875 kHz
25	789	755	758	793	798	767	720	646	100v	5925 kHz
26	739	628	698	755	749	653	595	530	100v	5975 kHz
27	707	574	649	731	739	595	492	440	100v	6025 kHz
28	689	574	646	728	724	580	426	453	100v	6075 kHz
29	646	574	673	694	716	580	433	347	100v	6125 kHz
30	636	604	643	746	707	544	401	401	100v	6175 kHz
31	585	551	621	742	731	522	482	392	100v	6225 kHz

Figure 12: 3-D Zone Plot; Raw Counts Parameter Values

3.3.4: Major_Frame / Electron Spectra Data

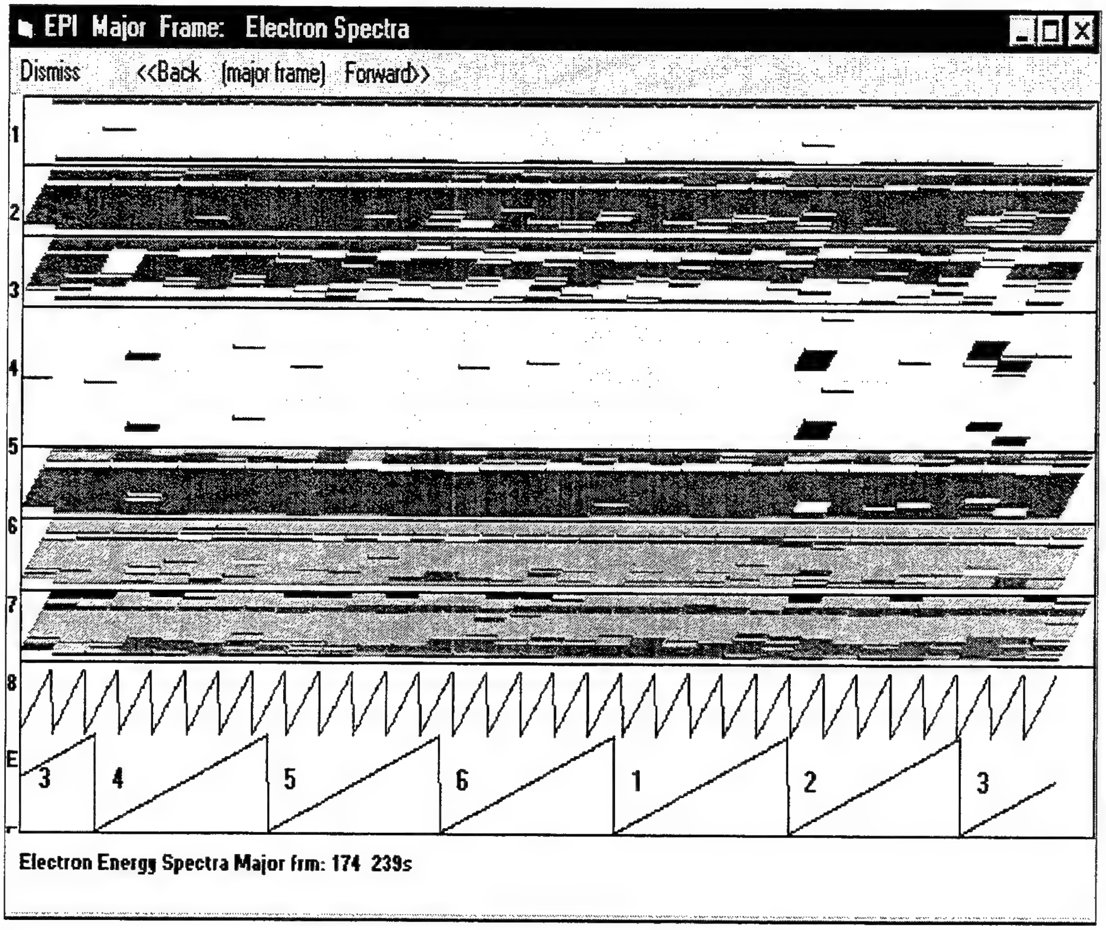


Figure 13: Electron Spectral Display

Spectra is displayed as a function of time during a major frame. Energy sweep and transmitter step displayed below as 2-D plots with minor frame numbering. The major frame can be advanced or retarded by menu clicks. Mouse clicking on the energy spectra brings up the same 2-d single energy spectrum plots as for the energy/flight time plots. Again, raw count numbers can be accessed by further mouse clicking as before.

3.3.5: Flight_Spectra/ Electron Frequency Resonances

Electron step count sums from a selected range of zones (3,4,5,6,7 in the example below) are plotted against TX frequency (0-8 MHz vertical) and time (horizontal).
Mouse clicking on this display provides a 2-D cut of electron counts versus TX frequency:

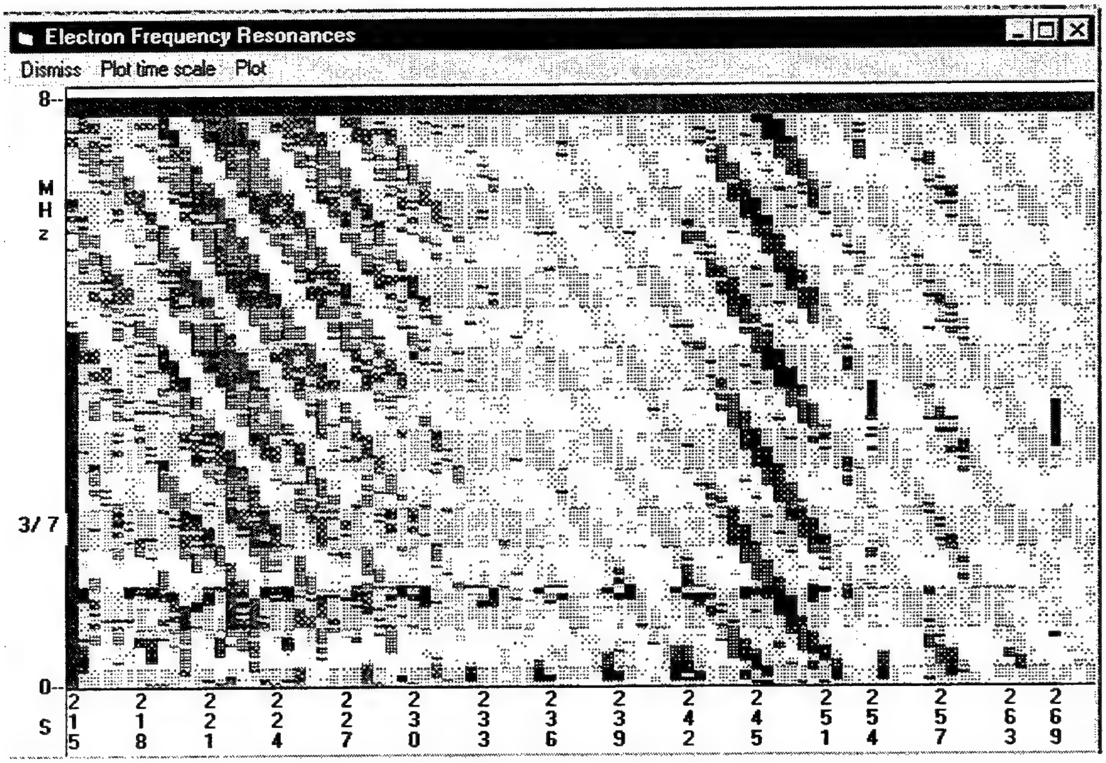


Figure 14: Electron Frequency Resonances Display

The electron energy sweep is also shown to help distinguish TX effects from energy spectral features

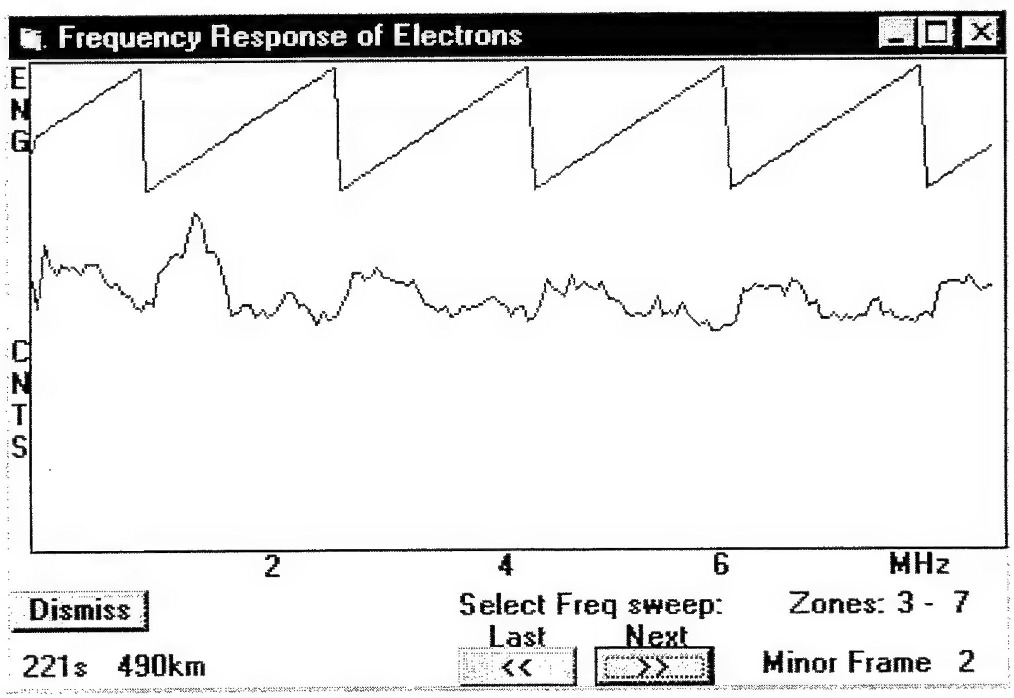


Figure 15: Electron Energy Sweep & Spectra

3.3.6: Millisecond Time Response Data

The millisecond time response data provides high time resolution measurements of the electron response to the TX pulse during a TX frequency step (EPI energy step). Data is presented in the form of 32 samples each of 90us duration through the 3.1ms energy step.

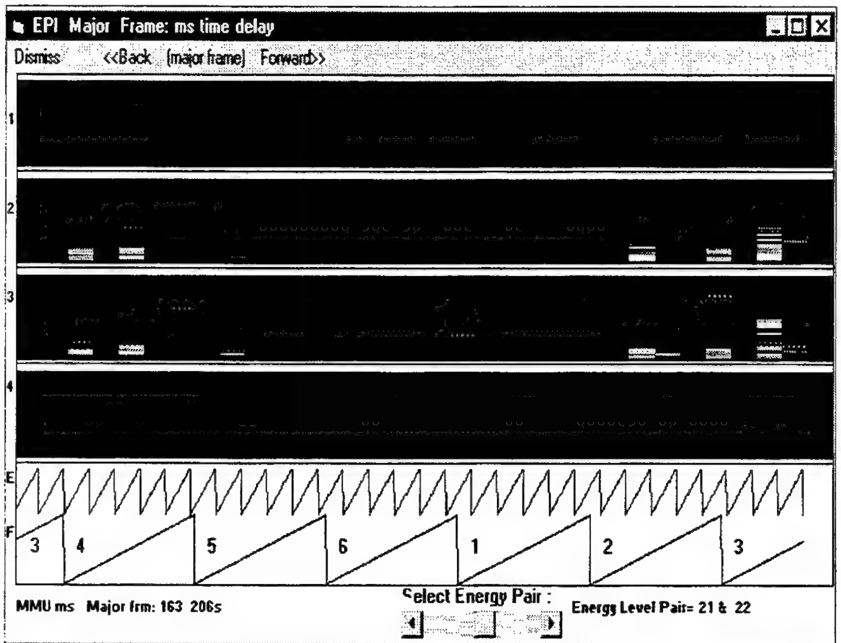


Figure 16: Milli-Second Time Delay Plot

The above Major_frame plot of time delays shows the time response of a selected energy pair over the course of a major frame. The energy pair displayed can be changed by the slider bar. The energy step, frequency step and minor frame are included in the lower 2-D plot. Major frame position can be moved forward or backward. A cursor click at any position (energy sweep) brings up the single energy sweep display below:

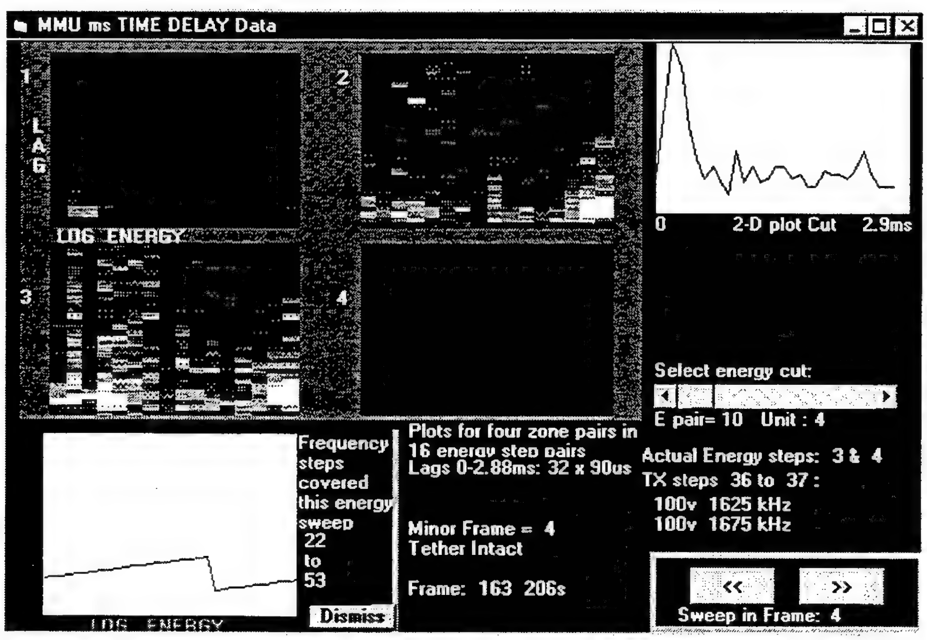


Figure 17: Energy Sweep ms Time Delay Plot

In its present form this window plots the ms time lags against the EPI CPU internal energy step number (0-31) starting at 0 at the beginning of a major frame. Hence the need for the 2-D plot to show real energy value and also TX frequency for this energy sweep. The energy sweep can be advanced/retarded by buttons. 2-D plots of electron counts versus time delay at top right are selected by cursor from the individual 3-D plots of the four zone pairs. The slider can also be used to move through energy level pairs

Clicking on a selected 2-D plot will bring up the raw count values of the 90us samples as shown below.

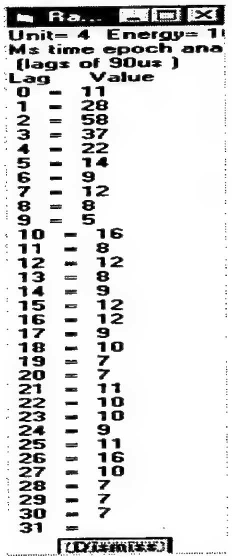


Figure 18: Raw Counts for Energy Sweep ms Time Delay Plot

In the following plot, for each major frame, and at each frequency of TX, the value plotted is the maximum difference between the beginning of the electron step (when the TX pulse occurs) and the end of the step. For this calculation the first 10 samples of 90us are summed and the last 10 samples of 90us subtracted. The count excess is divided by 10 so that the same mmu data scaling range applies for the color scale. As each spectrum is plotted the 2-D cut is displayed below.

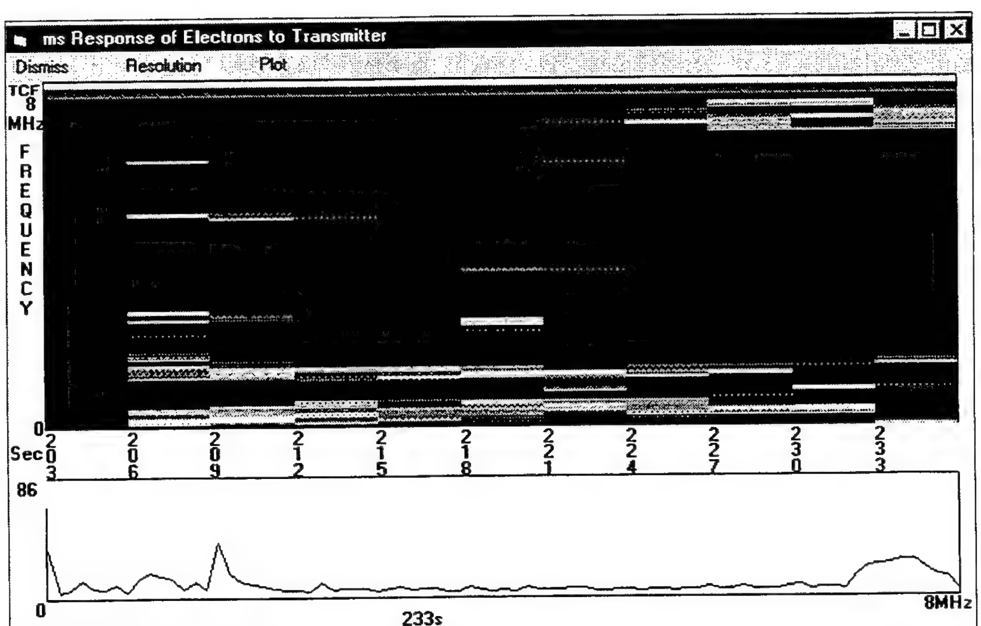


Figure 19: Flight_Spectra / TX ms Response

3.3.7: MHz Buncher Autocorrelator Data

0 - 8 MHz electron autocorrelators are implemented by the buncher algorithm. Here, histograms of electron time separations are accumulated over each electron step. Time separations are measured in units (or time lags) of a 16 MHz crystal clock up to 32 lags. As count rates are much lower than 16 MHz this can be shown to be equivalent to a full autocorrelator with little loss of information. This ACF provides measurements of both the electron response at MHz to the TX pulse as well as a measure of any natural wave-particle interactions.

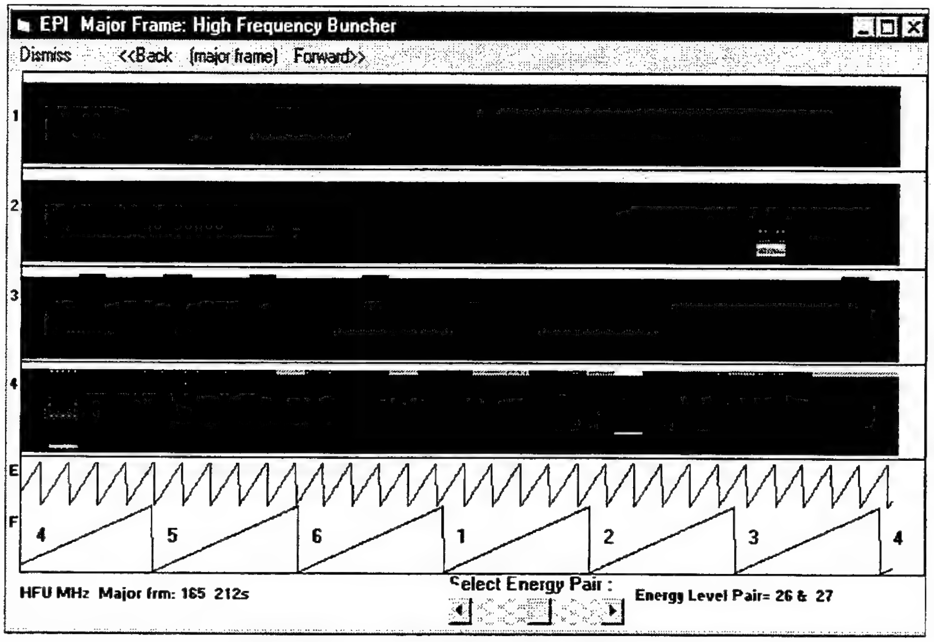


Figure 20: Major-Frame / Buncher

This plots ACF lag against time through a major frame for a selected energy pair for each of the four zone pairs. Energy pair displayed can be changed by slider. Major frame moved by forward/back clicks. A click on any position (energy sweep) brings up the single energy sweep display shown in Figure 20.

MHz ACF plot of lag versus energy for the four zones. A 2-D single ACF can be selected by the mouse for display at top right. Also, the transmitter frequency on that energy step is indicated below for comparison when the Transmitter is active at 1 or 100V. The frequency of any modulation present in the MHz ACF can be measured manually by matching the lines with the peaks as shown. This takes into account the electronics deadtime of the buncher (zero lag is not zero electron separation)

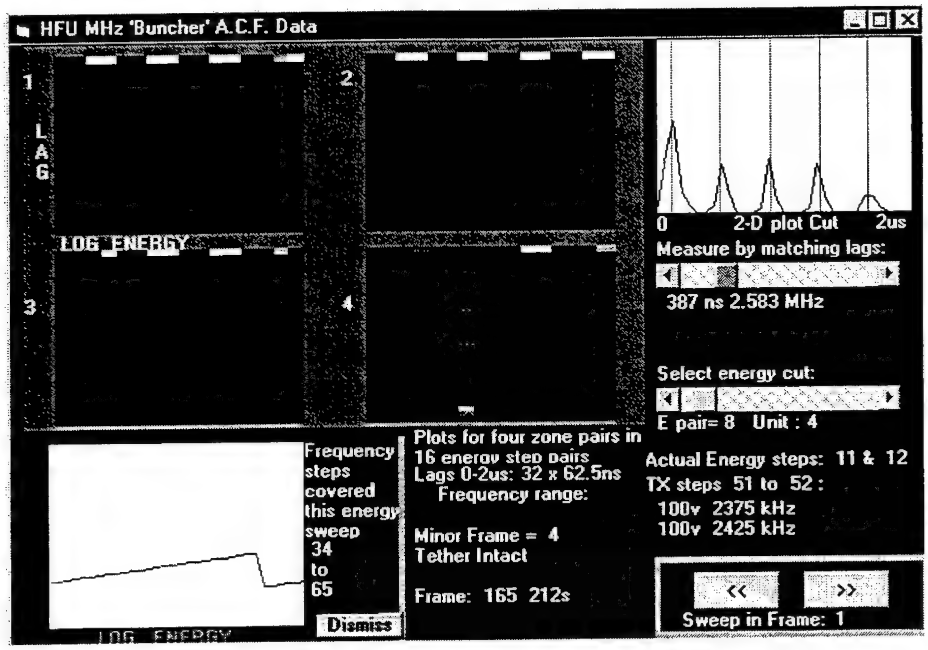


Figure 21: Energy Sweep MHz Plot

Clicking on the 2-D display will list the raw ACF values as shown below.

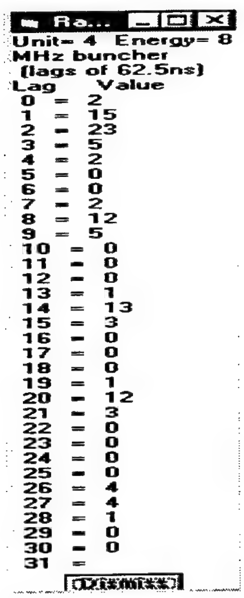


Figure 22: Raw Counts of Energy Sweep MHz Plot

Because the statistics of electron MHz ACF are generally poor for natural WPI studies this display allows longer summations. Also the active fixed frequency minor frame 6 can be studied. The frequency can be measured manually by sliding the lines across. This frequency measurement takes in to account electronics deadtime. Note the modulation is often observed in the 2-D cut (see below) superimposed on an overall exponential fall off that is due to the Poisson statistics of electron counting.

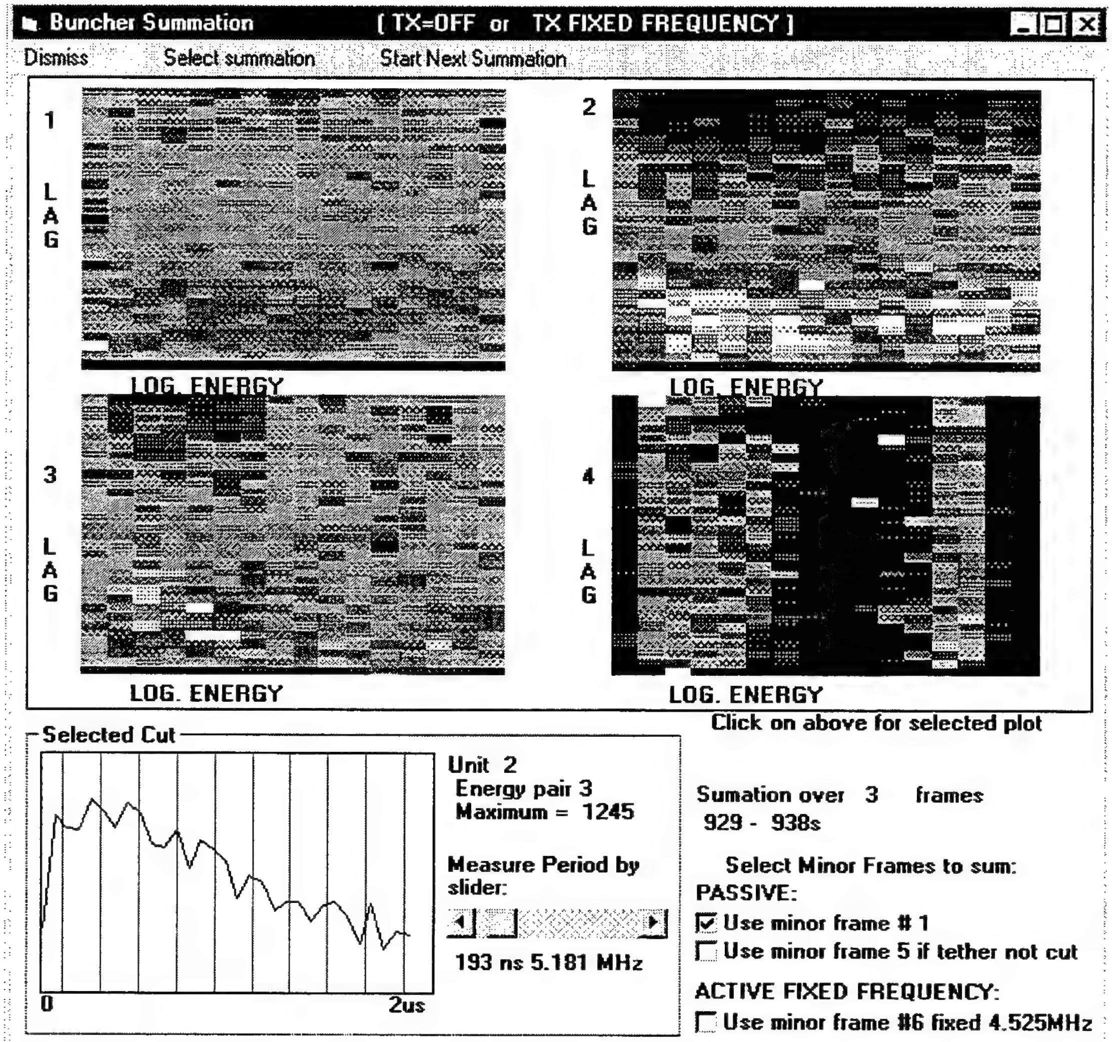


Figure 23: Flight-Spectra / Passive Buncher Summation

Note: Losses of synchronization in the dataset leads to strong horizontal lines across all energies. A fault in the Forward payload leads to gaps in energies covered.

4.0 TASK #3—LATUR EFFORTS

4.1 Program Definition

The objective of this task is to pursue the development of techniques to design and build miniaturized, low power and considerably more capable space experiment instrumentation. Current requirements necessitate reductions in size, mass, power consumption and telemetry bandwidth of diagnostic instruments on space platforms. Amptek, Inc's considerable expertise in this endeavor will be applied to realize such capability in new and innovative instruments.

A principal area of interest is in improving the performance of particle correlator hardware, while simultaneously reducing the size, mass and power requirements. Working with the Space Science Center (SSC) at the University of Sussex in the UK, Amptek, Inc. has been at the forefront of correlator development. The first correlator to be flown was provided by SSC in 1980. Since then, the collaborative effort has continually improved the capability of the units, by making use of the increased processing ability of new generations of hardware elements such as microprocessors and programmable gate arrays.

4.2 Summary of Activities

During the report period, an investigation was carried out into the various payload configurations which might be accommodated on a upcoming rocket launch opportunity to study wave-plasma interactions in the equatorial region. The *La*gmuir *Tur*bulence (LaTUR) program is a NASA sounding rocket program, with launches from Puerto Rico, and takes advantage of a nearby high power RF beam to heat and excite plasma waves in localized areas of the ionosphere. Active studies of the interaction of intense electromagnetic waves with the earth's ionospheric plasma are therefore possible, and the opportunity to carry out such controlled studies in the medium is unsurpassed.

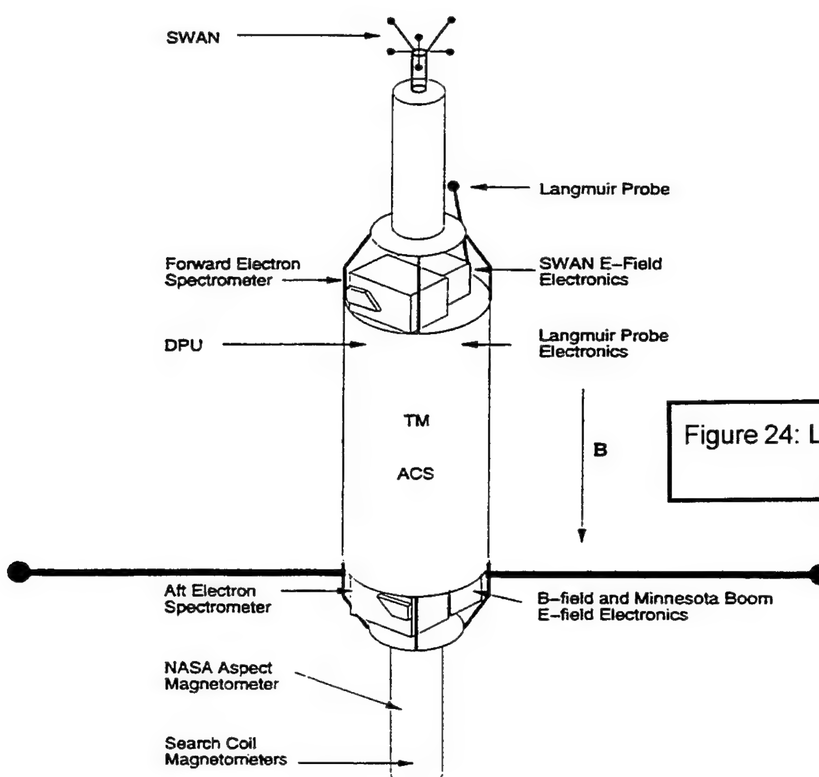


Figure 24: LaTUR Payload Complement

The LaTUR mission will inherit significant heritage from the recently concluded OEDIPUS-C program, in that the particle sensors (to be provided by AFRL/VBSB) and Data Processing hardware (DPU, provided by Amptek, Inc.) will be almost identical. The payload items will be identified in similar fashion as the Energetic Particle Instrument (EPI) and the physical size of the units will be identical to those provided for OEDIPUS-C. The same electronics box will be used for the DPU, as well as, functional units of identical design, but with the latest and thus enhanced performance, electronic components. Newer, faster processors now allow the possibility of multibit correlator operations to be carried out for example, whereas only single bit operations were possible for previous versions of the hardware.

A formal program launch occurred during early in the report period, and several meeting were held to define the hardware and telemetry requirements. A principal objective was to make use of as much OEDIPUS-C leftover hardware, circuit design features and GSE equipment as possible. Acting on this basis, the changes that were necessary to finalize the previous printed circuit board designs were relatively minimal, and the LaTUR flight boards were fabricated and built in relatively short order. The DPU enclosure itself was surplus hardware. A dimensioned schematic of the DPU is shown below in Figure 25.

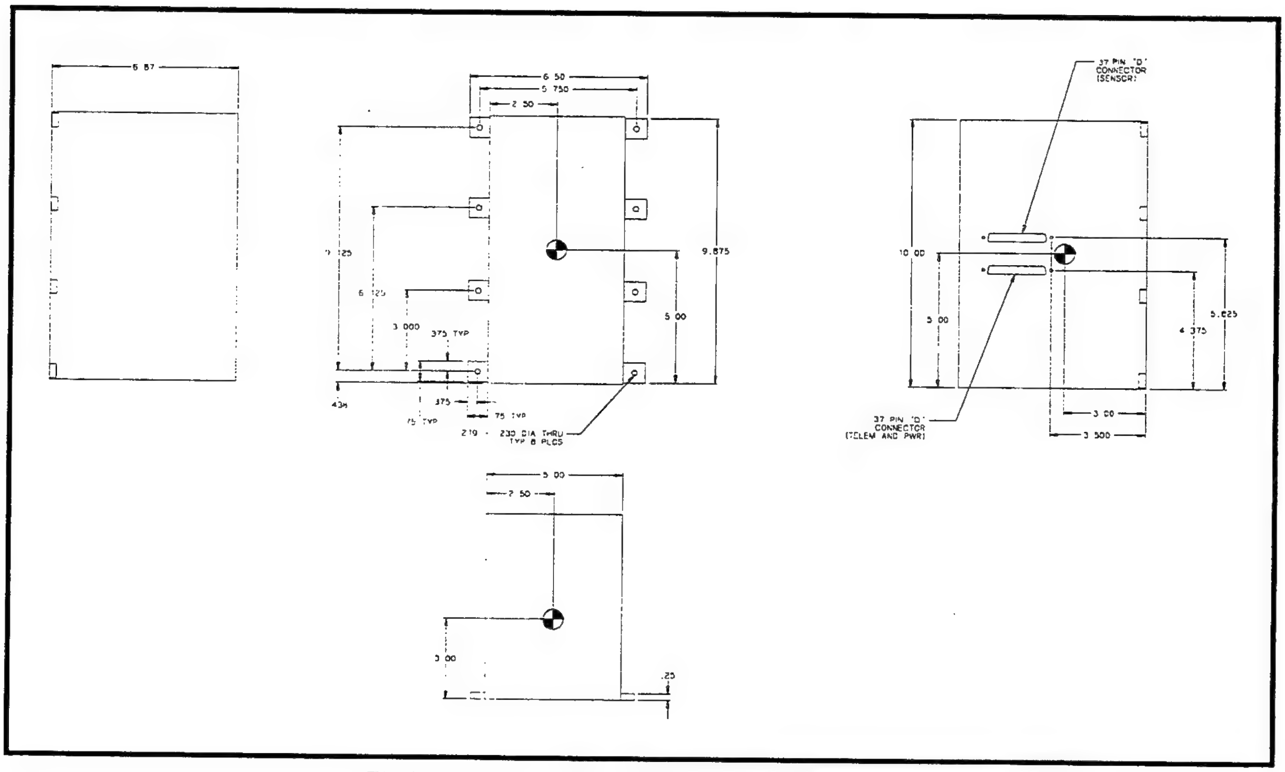


Figure 25: DPU Dimensioned Schematic

4.3 DPU Functionality

4.3.1 Normal Electron Spectra (Counters)

Electron pulses are counted by sixteen 16-bit counters directly accessible by the CPU bus. The counters are read at the end of each energy step to generate a normal electron spectrogram. These counts will be log scaled down to 8 bits.

7 sweeps x (up to) 32 energies $\Rightarrow$ 2,104 words / experiment frame $\Rightarrow$ 121,759 bits/s

4.3.2 High Frequency Units (HFU)

Particle correlation is used to look for modulations caused in the particles when the transmitter frequency corresponds to a plasma resonance. High frequency correlation in the range 0 to 8 MHz (transmitter frequency range) will use the 'buncher technique' used on SPREE. Energy analysis will be done in pairs of adjacent energies since the frequency difference is small between adjacent frequency steps. Each of eight HFUs will generate 2 dimensional histograms - 16 energies x 32 lags. As each histogram is read out once per energy sweep the values are small enough to transmit only byte wide values.

$$8 \text{ HFU} \times 7 \text{ sweeps} \times (\text{up to}) \ 32 \text{ energies} \times 64 \text{ lags} \Rightarrow 45{,}112 \text{ words / experiment frame}$$
$$\Rightarrow 2{,}610{,}648 \text{ bits/s}$$

As the total data from HFU within a major frame can be up to 65,536 bytes a whole segment of the 80C286 memory is devoted to this data.

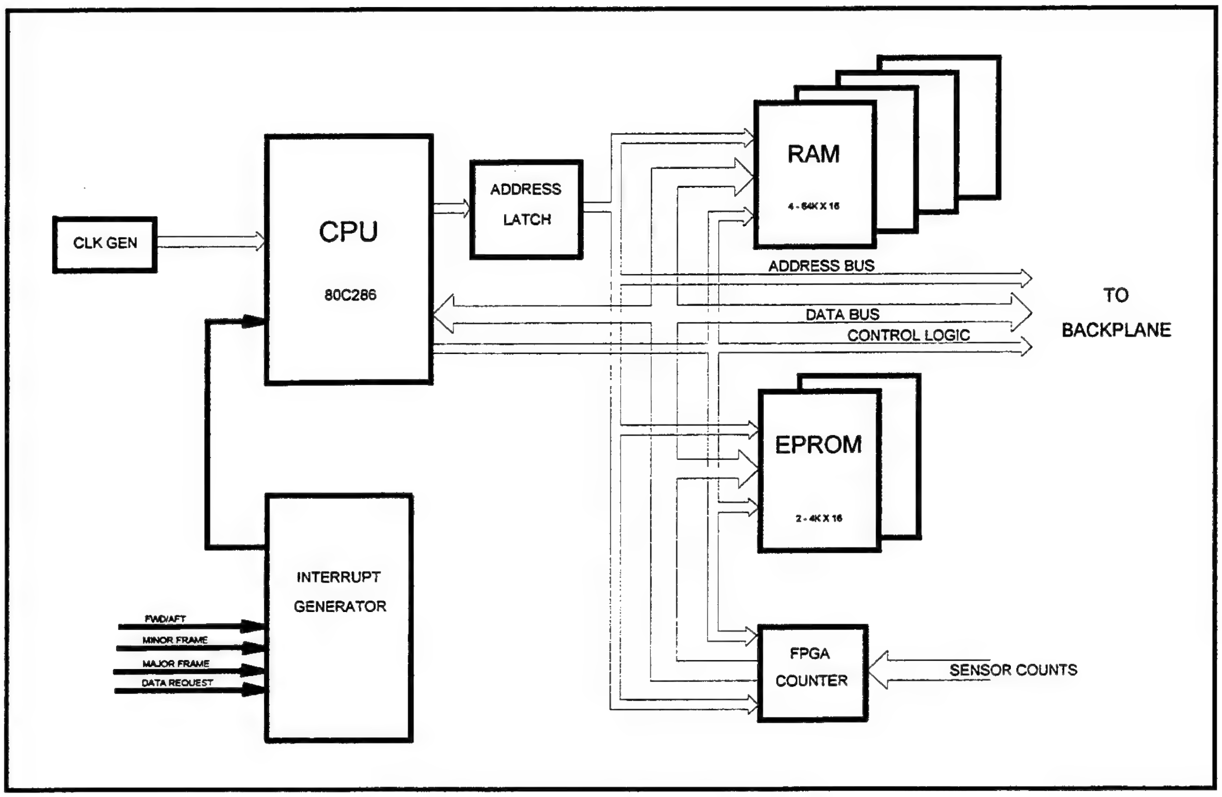


Figure 26: CPU Board Schematic

4.3.3 Central Processing Unit, CPU

All inputs into the EPI Electronics Module are accessible to the CPU. In addition; the CPU has direct interface with the HFU. It outputs telemetry via a FIFO buffer.

4.3.3.1 EPI Electronics Module CPU Interface

The following inputs are accessible to the CPU from the Electronics Module interface:

(a) 16 electron pulse streams
(b) PRF pulses
(c) Major frame toggle
(d) Fore/Aft command switch
(e) telemetry data request
(f) Energy level

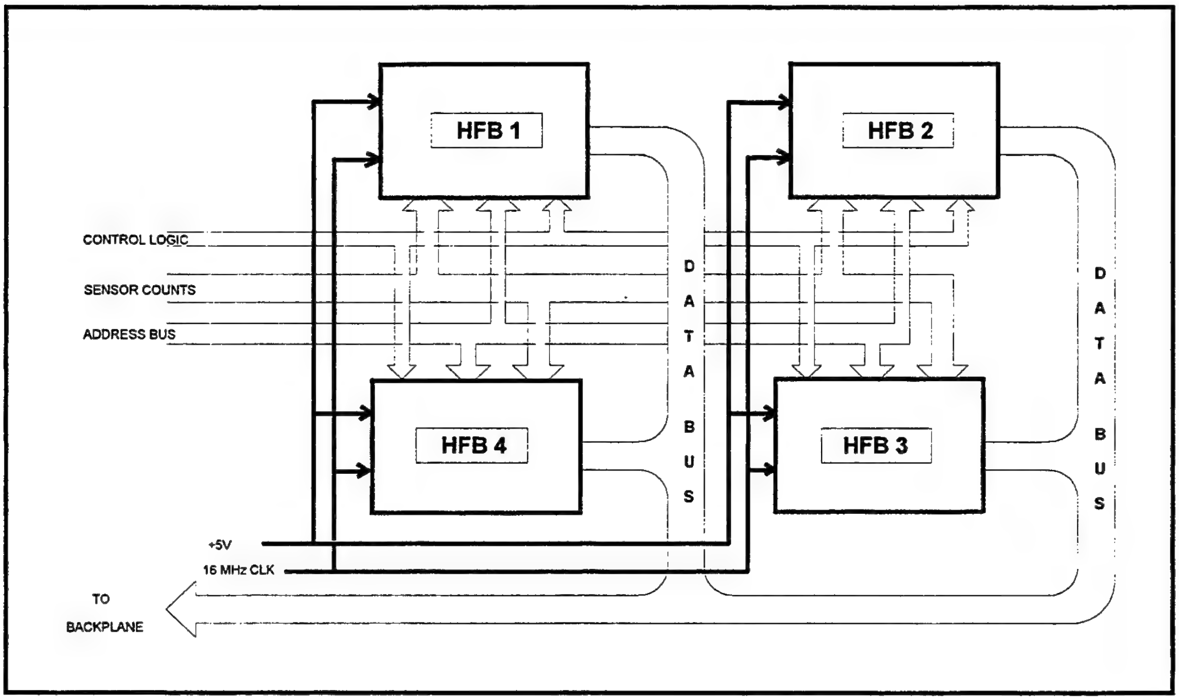


Figure 27: High Frequency Board Schematic

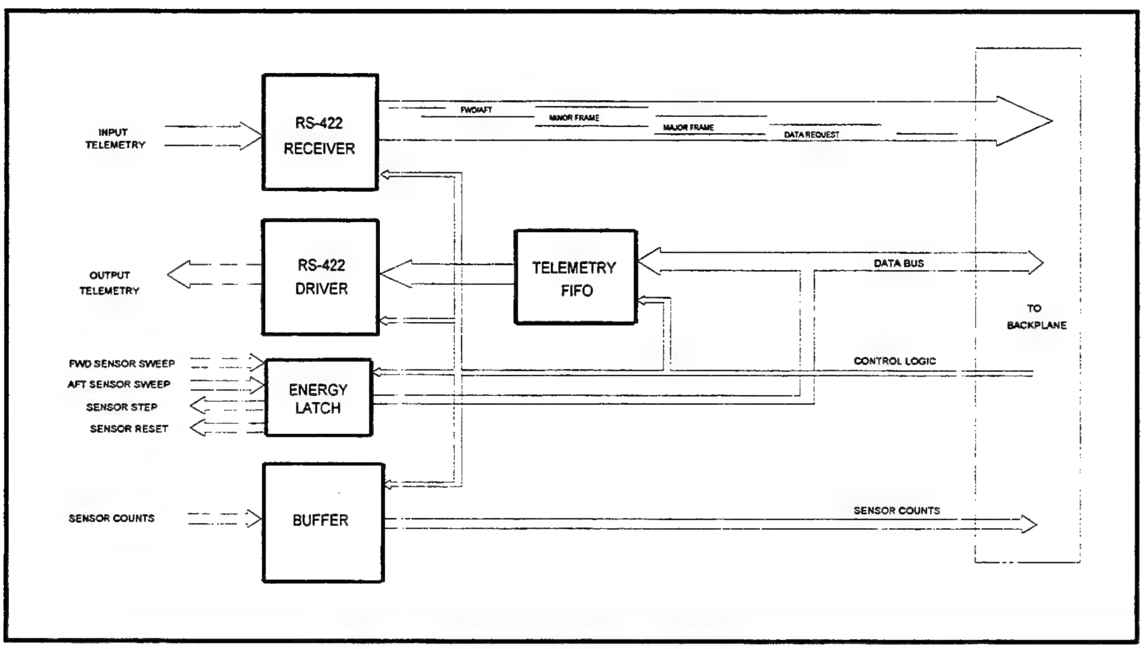


Figure 28: Interface Board Schematic

The EPI Electronics Module outputs data from the CPU in one combined stream. The data in the CPU is double buffered, with one buffer corresponding to the previous major frame's measurements being read out to the telemetry, while the other is being prepared with the current major frame's measurements. The sequence of the data is as follows:

4.3.4 Spectra Data

The next bytes are in time sequence of actual energy steps throughout the frame. Each 9 bytes output per energy level are that next energy level value followed by the 8 log counts of the 8 input streams summed over the previous energy level.

4.3.5 HFU Data

The first two bytes of this block of 65,536 bytes are the synch values: 5AH, AAH

The data following the synch bytes is then ordered in time with a block of 2,048 bytes HFU data for each block of 32 actual energy levels through the major frame starting from the first in the frame. Each block of 2,048 bytes is 512 bytes from HFU unit 1,..512 bytes HFU 2,..512 bytes HFU 4. Each HFU unit being data from an electron input streams. Each block of 512 bytes are lags 1 to 32 energy pair 1, lags 1 to 32 energy pair 2 etc. to energy pair 16.

4.3.6 Overall Data Rate

A breakdown of the constituent elements within the telemetry stream which are outputted by the CPU is as follows:

	Bits per second
HFU	2,610,648
Spectral	121,759
SOH	9,375
Filler	33,044
Major Frame Synch	179
Total	2,775,005

For a 616 seconds flight, the overall rocket flight data will amount to some 214 Megabytes and could easily be stored on the hard disc of the GSE PC, or that used to analyze the data post-flight.

4.4 LATUR Telemetry Format

A general description of the output data from the instrument is presented in the following material.

4.4.1 Major Frame - Experiment Frame

The experiment data is essentially asynchronous to the encoder telemetry with the exception that timing of the energy steps is determined by the minor frame clock (9 Minor frames per step).

The data will be encoded into a single experiment frame which contains the data from 7 HFB sweeps, 7 spectral sweeps, 8 SOH and a filler for a total of 23 minor frames per experiment frame.

The last word in an Experiment Frame will be a MAJOR FRAME SYNCH WORD.

MAJOR SYNCH WORD

The last word of an experiment frame will contain a synch word of FA F3 20 h.

MINOR FRAMES

Minor Frames are a variable length format. The length in words of the minor frame is encoded into the minor frame ID word.

Minor frames contain a MINOR FRAME SYNCH WORD followed by a MINOR FRAME ID WORD which is the followed by the minor frame data.

WORD LENGTH

The encoder used on the LATUR mission has a 10 bit word length. All DPU data is 8 bits wide with the 2 LSB's hardwired to 0. All references to words in this document will be DPU (8 bit) words with the assumption of the 2 LSB's of the encoder word = 0.

4.4.2 Implementation

MAJOR FRAME SYNCH WORD

The last word in an experiment frame will contain the sequence FA F3 20 h.
This word appears every experiment frame (47952 words).

MINOR FRAME SYNCH WORD

The first word in a minor frame will contain 5Ah

MINOR FRAME ID WORD

The second-fourth word in a minor frame will be a Minor Frame ID word which is a sequence of: a value of 0-FFh (ID) followed by the length in words of the following data (0-FFFF).

MINOR FRAME 0

This identifies the state of health minor frame.

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	00	Minor Frame ID (SOH)	00	00
2	0A	Subframe Length lsb	0A	0A
3	00	Subframe Length msb	00	00
4	XX	Experiment Frame Count lsb	00	FF
5	XX	Experiment Frame Count lsb	00	FF
6	XX	Encoder MajFr count lsb	00	FF
7	XX	Encoder MajFr count msb	00	FF
8	XX	Minor Frame Count lsb	00	FF
9	XX	Minor Frame Count msb	00	FF
10	XX	under run count lsb	00	FF
11	XX	under run count msb	00	FF
12	XX	Sweep Count LSB	00	FF
13	XX	Sweep ID	00	FF
14	XX	STATUSWORD lsb	00	FF
15	XX	STATUSWORD msb	00	FF

MINOR FRAME ID 01

This Identifies sweep style 1 (32 steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	01	Minor Frame ID (sweep 1)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-2051	XX	EPI 1/9 HFB data	00	FF
2052-4099	XX	EPI 2/10 HFB data	00	FF
4100-6147	XX	EPI 3/11 HFB data	00	FF
6148-8195	XX	EPI 4/12 HFB data	00	FF

MINOR FRAME ID 01 (CONT'D)

Position	Nominal Value	Function	Minimum	Maximum
8196-10243	XX	EPI 5/13 HFB data	00	FF
10244-12291	XX	EPI 6/14 HFB data	00	FF
12292-14339	XX	EPI 7/15 HFB data	00	FF
14340-16387	XX	EPI 8/16 HFB data	00	FF
16388	XX	Sweep Count lsb	00	FF
16389	XX	Sweep ID	00	FF
16390	XX	STATUSWORD lsb	00	FF
16391	XX	STATUSWORD msb	00	FF

MINOR FRAME ID 02

This Identifies sweep style 2 (32 steps, data summed over consecutive steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	02	Minor Frame ID (sweep 1)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-1027	XX	EPI 1/9 HFB data	00	FF
1028-2051	XX	EPI 2/10 HFB data	00	FF
2052-3075	XX	EPI 3/11 HFB data	00	FF
3076-4099	XX	EPI 4/12 HFB data	00	FF
4100-5123	XX	EPI 5/13 HFB data	00	FF
5124-6147	XX	EPI 6/14 HFB data	00	FF
6148-7171	XX	EPI 7/15 HFB data	00	FF
7172-8195	XX	EPI 8/16 HFB data	00	FF
8196	XX	Sweep Count lsb	00	FF
8197	XX	Sweep ID	00	FF
8198	XX	STATUSWORD lsb	00	FF
8199	XX	STATUSWORD msb	00	FF

MINOR FRAME ID 03

This Identifies sweep style 3 (16 steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	03	Minor Frame ID (sweep X)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-1027	XX	EPI 1/9 HFB data	00	FF
1028-2051	XX	EPI 2/10 HFB data	00	FF
2052-3075	XX	EPI 3/11 HFB data	00	FF
3076-4099	XX	EPI 4/12 HFB data	00	FF
4100-5123	XX	EPI 5/13 HFB data	00	FF
5124-6147	XX	EPI 6/14 HFB data	00	FF
6148-7171	XX	EPI 7/15 HFB data	00	FF
7172-8195	XX	EPI 8/16 HFB data	00	FF
8196	XX	Sweep Count lsb	00	FF
8197	XX	Sweep ID	00	FF
8198	XX	STATUSWORD lsb	00	FF
8199	XX	STATUSWORD msb	00	FF

Minor Frame ID 04

This Identifies sweep style 1 (16 steps, data summed over consecutive steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	04	Minor Frame ID (sweep X)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-515	XX	EPI 1/9 HFB data	00	FF
516-1027	XX	EPI 2/10 HFB data	00	FF
1028-1539	XX	EPI 3/11 HFB data	00	FF
1540-2051	XX	EPI 4/12 HFB data	00	FF
2052-2563	XX	EPI 5/13 HFB data	00	FF
2564-3075	XX	EPI 6/14 HFB data	00	FF
3076-3587	XX	EPI 7/15 HFB data	00	FF
3588-4099	XX	EPI 8/16 HFB data	00	FF
4100	XX	Sweep Count lsb	00	FF
4101	XX	Sweep ID	00	FF
4102	XX	STATUSWORD lsb	00	FF
4103	XX	STATUSWORD msb	00	FF

Minor Frame ID 05

This Identifies sweep style 5 (16 steps, data summed over consecutive steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	05	Minor Frame ID (sweep X)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-600	AA	Filler	AA	AA
601	XX	Sweep Count lsb	00	FF
602	XX	Sweep ID	00	FF
603	XX	STATUSWORD lsb	00	FF
604	XX	STATUSWORD msb	00	FF

Minor Frame ID 81, 82

This Identifies spectral sweep style (32 steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	81/82	Minor Frame ID (sweep 1)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-35	XX	EPI 1 spectral data (32 steps)	00	FF
36-67	XX	EPI 2 spectral data (32 steps)	00	FF
68-99	XX	EPI 3 spectral data (32 steps)	00	FF
100-131	XX	EPI 4 spectral data (32 steps)	00	FF
132-163	XX	EPI 5 spectral data (32 steps)	00	FF
164-195	XX	EPI 6 spectral data (32 steps)	00	FF
196-227	XX	EPI 7 spectral data (32 steps)	00	FF
228-259	XX	EPI 8 spectral data (32 steps)	00	FF
260-291	XX	EPI 9 spectral data (32 steps)	00	FF
292-323	XX	EPI 10 spectral data (32 steps)	00	FF
324-355	XX	EPI 11 spectral data (32 steps)	00	FF
356-387	XX	EPI 12 spectral data (32 steps)	00	FF
388-419	XX	EPI 13 spectral data (32 steps)	00	FF
420-451	XX	EPI 14 spectral data (32 steps)	00	FF
452-483	XX	EPI 15 spectral data (32 steps)	00	FF
484-515	XX	EPI 16 spectral data (32 steps)	00	FF
516	XX	Sweep Count lsb	00	FF

Minor Frame ID
81, 82 (Cont'd)

Position	Nominal Value	Function	Minimum	Maximum
517	XX	Sweep ID	00	FF
518	XX	STATUSWORD lsb	00	FF
519	XX	STATUSWORD msb	00	FF

MINOR FRAME ID 83, 84

This Identifies spectral sweep style 1 (16 steps)

Position	Nominal Value	Function	Minimum	Maximum
0	5A	Minor Frame Synch Word	5A	5A
1	83/84	Minor Frame ID (sweep 1)	01	01
2	00	Subframe Length lsb	02	02
3	20	Subframe Length msb	20	20
4-19	XX	EPI 1 spectral data (16 steps)	00	FF
20-35	XX	EPI 2 spectral data (16 steps)	00	FF
36-51	XX	EPI 3 spectral data (16 steps)	00	FF
52-67	XX	EPI 4 spectral data (16 steps)	00	FF
68-83	XX	EPI 5 spectral data (16 steps)	00	FF
84-99	XX	EPI 6 spectral data (16 steps)	00	FF
100-115	XX	EPI 7 spectral data (16 steps)	00	FF
116-131	XX	EPI 8 spectral data (16 steps)	00	FF
132-147	XX	EPI 9 spectral data (16 steps)	00	FF
148-163	XX	EPI 10 spectral data (16 steps)	00	FF
164-179	XX	EPI 11 spectral data (16 steps)	00	FF
180-195	XX	EPI 12 spectral data (16 steps)	00	FF
196-211	XX	EPI 13 spectral data (16 steps)	00	FF
212-227	XX	EPI 14 spectral data (16 steps)	00	FF
228-243	XX	EPI 15 spectral data (16 steps)	00	FF
244-259	XX	EPI 16 spectral data (16 steps)	00	FF
260	XX	Sweep Count lsb	00	FF
261	XX	Sweep ID	00	FF
242	XX	STATUSWORD lsb	00	FF
263	XX	STATUSWORD msb	00	FF

Frame Layout

Function	ID code	# words
SOH	00	16
32 step HFB	01	16392
32 step spectral	81	520
SOH	00	16
16 step HFB	03	8200
16 step spectral	83	264
SOH	00	16
16 step HFB (summed consecutive levels)	04	4104
16 step spectral	84	264
SOH	00	16
16 step HFB (summed consecutive levels)	04	4104
16 step spectral	84	264
SOH	00	16
16 step HFB (summed consecutive levels)	04	4104
16 step spectral	84	264
SOH	00	16
16 step HFB (summed consecutive levels)	04	4104
16 step spectral	84	264
SOH	00	16

Frame Layout (Cont'd)

Function	ID code	# words
16 step HFB (summed consecutive levels)	04	4104
16 step spectral	84	264
SOH	00	16
Filler	05	605
	Major Frame Sync	3

Table 23: LaTUR Telemetry Structure

Latur Telemetry Layout

(variable length subframes)

Sub Frame	Synch Word	SF ID (hex)	SubFrame Length (hex) ls	ms	SubFrame Data (dec)	Sweep Count Experiment	Sub-sweep	Status Word		# words (8bit)	
1	5A	00	0E	00	10	XX	-1	XX	XX	18	SOH
2	5A	05	59	02	411	XX	-1	XX	XX	419	Filler
3	5A	00	0E	00	10	XX	0	XX	XX	18	SOH
4	5A	01	04	40	16384	XX	0	XX	XX	16392	HFB (32 step)
5	5A	81	04	02	512	XX	0	XX	XX	520	Spectral (32 step)
6	5A	00	0E	00	10	XX	1	XX	XX	18	SOH
7	5A	04	04	20	4096	XX	1	XX	XX	4104	HFB (16 step summed consecutive steps)
8	5A	84	04	01	258	XX	1	XX	XX	264	Spectral (16 step)
9	5A	00	0E	00	10	XX	2	XX	XX	18	SOH
10	5A	04	04	10	4096	XX	2	XX	XX	4104	HFB (16 step summed consecutive steps)
11	5A	84	04	01	256	XX	2	XX	XX	264	Spectral (16 step)
12	5A	00	0E	00	10	XX	3	XX	XX	18	SOH
13	5A	84	04	20	8192	XX	3	XX	XX	8200	HFB (16 step)
14	5A	84	04	01	256	XX	3	XX	XX	264	Spectral (16 step)
15	5A	00	0E	00	10	XX	4	XX	XX	18	SOH
16	5A	04	04	10	4096	XX	4	XX	XX	4104	HFB (16 step summed consecutive steps)
17	5A	84	04	01	256	XX	4	XX	XX	264	Spectral (16 step)
18	5A	00	0E	00	10	XX	5	XX	XX	18	SOH
19	5A	04	04	10	4096	XX	5	XX	XX	4104	HFB (16 step summed consecutive steps)
20	5A	84	04	01	256	XX	5	XX	XX	264	Spectral (16 step)
21	5A	00	0E	00	10	XX	6	XX	XX	18	SOH
22	5A	04	04	10	4096	XX	6	XX	XX	4104	HFB (16 step summed consecutive steps)
23	5A	84	04	01	256	XX	6	XX	XX	264	Spectral (16 step)
24	5A	00	0E	00	10	XX	-1	XX	XX	18	SOH
25	5A	6	59	02	144	XX	-1	XX	XX	152	Filler
Maj Fr Synch	FA	F3	20							3	
									Frame length (words)	47952	
									Frame length (bits)	383616	
									Data Bit Rate	2220000	
									Bit rate with 10/8 penalty	2775000	